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August 1996

US Army Corps of Engineers
Waterways Experiment Station

Geoacoustic Study of Delaware Main Channel

by Richard G. McGee

WES

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Prepared for U.S. Army Engineer District, Philadelphia

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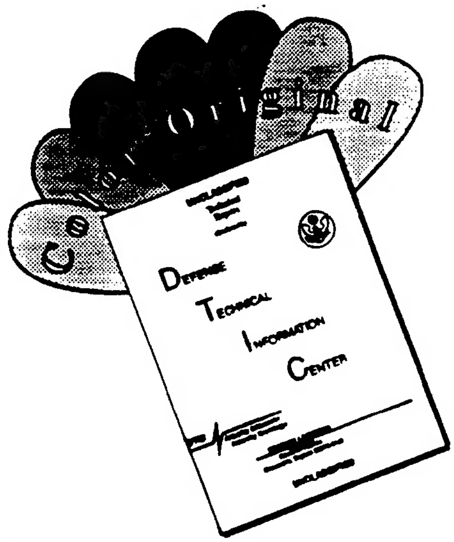

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by Richard G. McGee

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Final report

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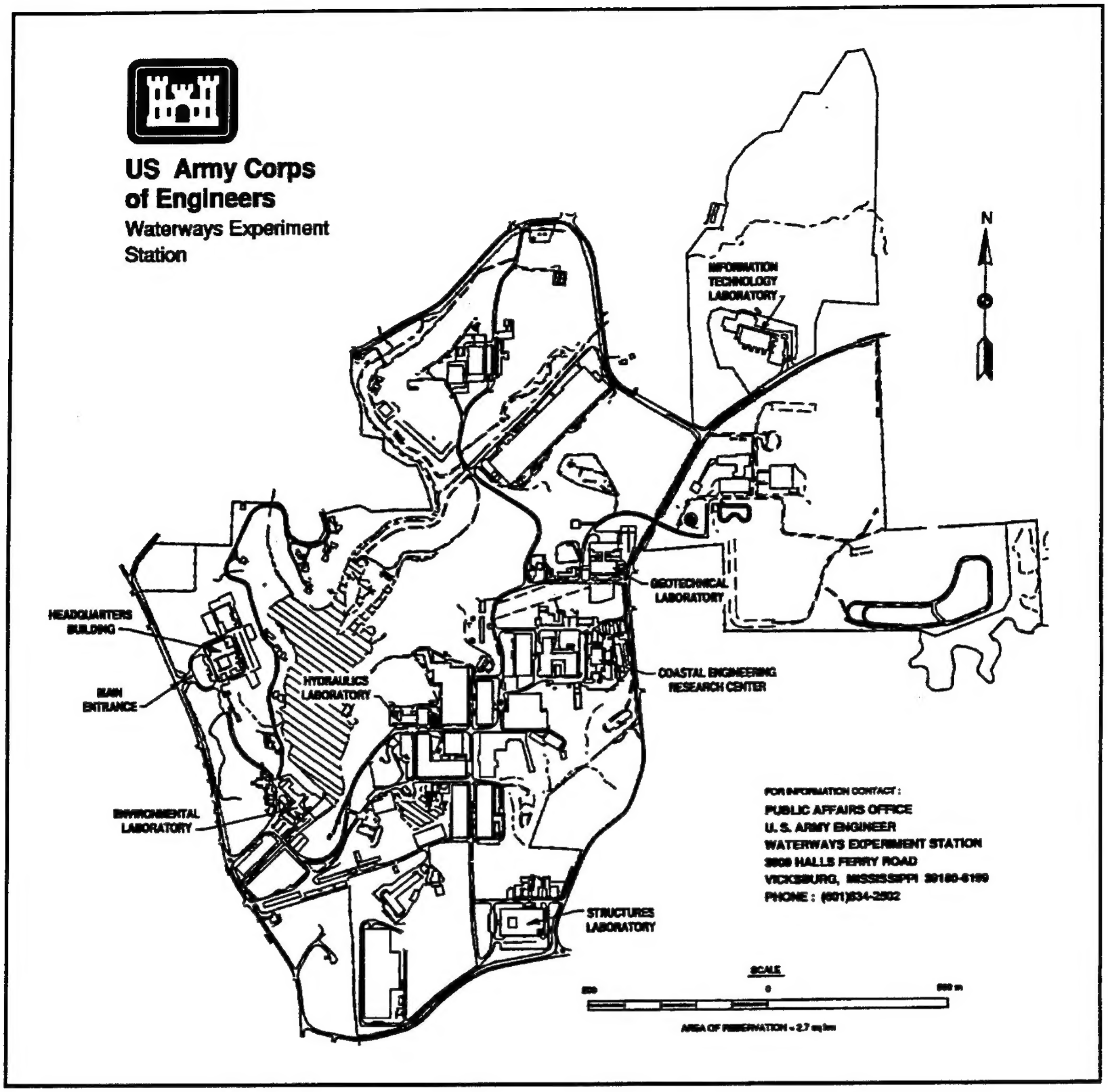

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Contents

Preface

A geoacoustic study of the Delaware River Main Channel from Philadelphia, PA, to the east end of Delaware Bay near Cape Henlopen, Delaware, and Cape May, New Jersey, was conducted by personnel of the Hydraulics (HL) and Geotechnical (GL) Laboratories, U.S. Army Engineer Waterways Experiment Station (WES). The field work was performed during August 1993. The investigation was performed under sponsorship of the U.S. Army Engineer District, Philadelphia (CENAP). The CENAP Project Engineer was Mr. Tony DePasquale.

The overall test program was conducted under the general supervision of Messrs. Frank A. Herrmann, Jr, Director, HL; Richard A. Sager, Assistant Director, HL; and Glenn A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. Mr. Richard G. McGee, Hydraulic Analysis Branch, HSD, was the Principal Investigator. This project is a cooperative effort with GL under the supervision of Drs. William F. Marcuson III, Director, GL; and Arley G. Franklin, Chief, Earthquake Engineering and Geosciences Division (EEGD), GL. This report was prepared by Mr. McGee under the supervision of Dr. Bobby J. Brown, Chief, Hydraulic Analysis Branch. Instrumentation support was provided by Mr. Tom S. Harmon, Jr., EEGD. Data collection and analysis assistance during this study were provided by Mr. Rodney L. Leist, EEGD, and, Ms. Janie M. Vaughan and Mr. Brian Williams, HSD. Technical assistance was also provided by Mr. David Caulfield, Caulfield Engineering, Oyama, BC, Canada.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multipy	By	To Obtain
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
miles (nautical)	1.853	kilometers

1 Introduction

Background

The U.S. Army Engineer District, Philadelphia, is currently preparing a Design Memorandum for the Delaware River Main Channel Preconstruction and Engineering Design Study. The study is focused on deepening of the Delaware River Main Channel from 40 to 45 ft.[1] The study area (Figure 1) encompasses the main shipping channel from approximately station 13+769 at the Ben Franklin Bridge in Philadelphia, PA, to the east end of Delaware Bay at station 511+696. A comprehensive subsurface exploration program has been initiated by the Philadelphia District to thoroughly characterize the bottom sediments to be dredged. Twenty-nine vibracores were collected within this 90-mile section of the main shipping channel in July 1991. To better characterize the vertical and lateral extent of all sediment units within areas to be dredged, an acoustic subbottom profile was requested to complement the existing core data.

The U.S. Army Engineer Waterways Experiment Station (WES) has developed a high-resolution seismic reflection technique to quantitatively assess the characteristics of bottom and subbottom marine sediments (McGee, Ballard, and Caulfield 1995). The technique describes marine sediments in terms of engineering properties, i.e., density, mean grain size, soil classification, and provides a contiguous picture of the horizontal and vertical extents of those properties. The Philadelphia District requested application of this technique in support of the Delaware River Main Channel design study.

Overview of Site Geology

The Delaware River Main Channel follows the Delaware River Channel from near Trenton, NJ, through Delaware Bay to its entrance to the Atlantic Ocean between Cape May, New Jersey, and Cape Henlopen, Delaware.

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[1] A table of factors for converting non-SI units of measurement to SI units is found on page vi.

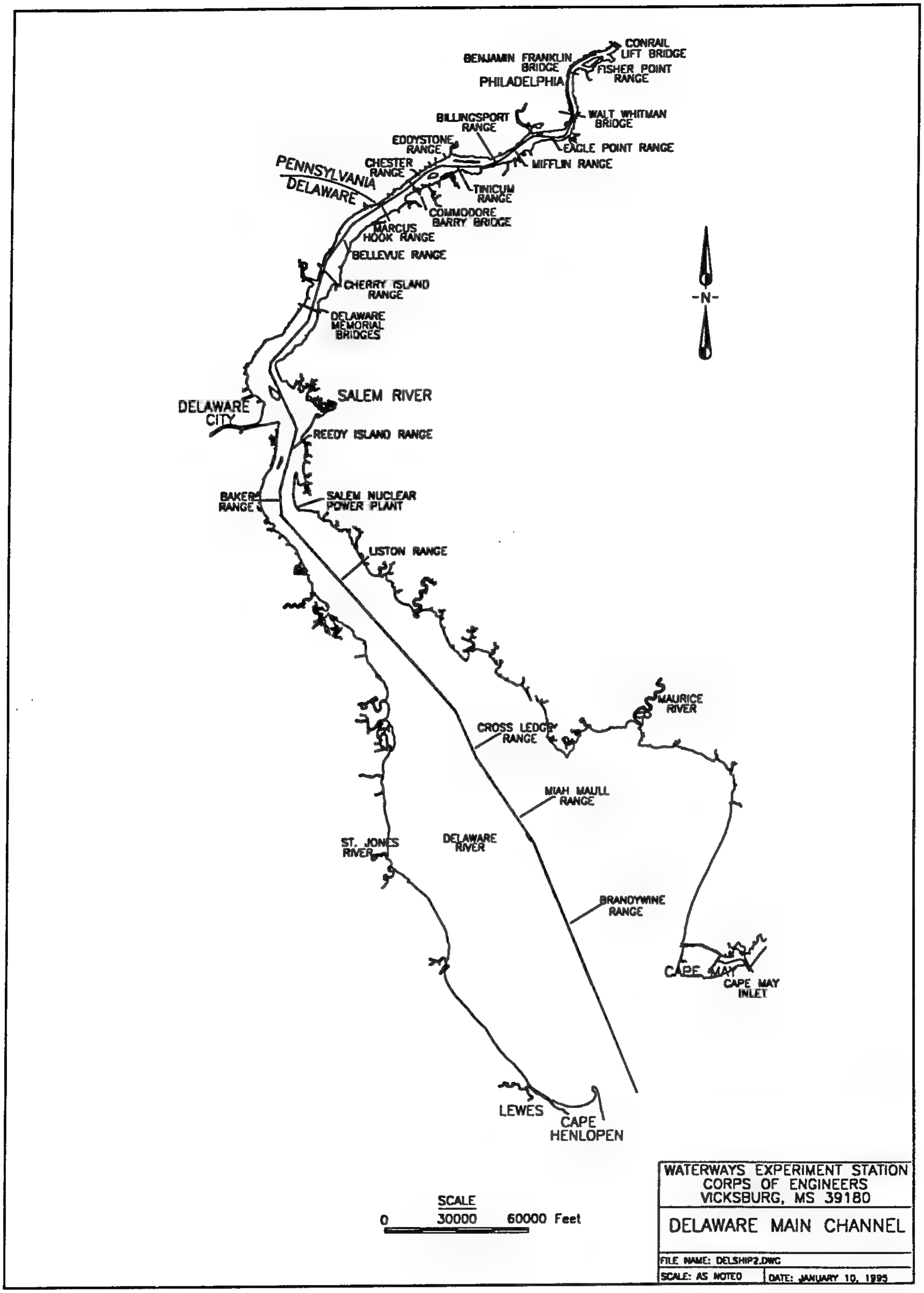


Figure 1. Delaware River Main Channel and vicinity

Navigation improvements to provide widening and deepening of the channel began following the River and Harbors Act of 1885. The present 40-ft channel was authorized in 1938 as far north as the Philadelphia Navy Yard (approximately station 50+000), with a 37-ft channel up to station 13+769 at the Ben Franklin Bridge. The 40-ft channel was extended to within 6 miles of Trenton beginning in 1959.

As reported by Weil (1977), the Delaware Estuary between Trenton and New Castle, DE, parallels the Fall Line with early Paleozoic metamorphic rocks of the Piedmont on the west and unconsolidated Coastal Plain sediments on the east as illustrated in Figure 2. Both materials are found in this portion of the navigation channel. South of New Castle, the lower tidal river and Delaware Bay are underlain by the sediments of the Atlantic Coastal Plain.

The bulk of sediment deposition in the estuary occurs in the dredged navigation channel and anchorage areas between the head of Delaware Bay and Philadelphia. Organic-rich silty clays and clayey silts characterize existing sediments deposited in this zone of rapid deposition.

The bay portion of the navigation channel is fairly straight and is bounded by numerous linear sand shoals. Sediments within the channel are predominantly fine to coarse sands. The channel depths are basically natural, requiring no dredging to maintain the authorized channel depth of 40 ft. South of Brown Shoal the river channel is no longer confined by sand shoals and becomes bathymetrically indistinct from the natural bay bottom.

Objective

The objective of this study was to quantify the bottom and subbottom sediments in terms of in situ density and soil type to a depth of about 20 ft, where possible, below the bottom of the existing ship channel (Figure 1). Only a single profile line was requested to be surveyed down the center line of the channel. Where applicable, data from the 29 vibracores already collected were correlated with the continuous acoustic reflection data to develop a geoacoustic model of the study area, providing a thorough characterization of the bottom and subbottom sediments, with emphasis on the top 5 ft of sediment. The results will also facilitate the accurate positioning and optimal placement of additional borings as may be required should anomalous or unexpected sediment units be encountered. Since the cores were retrieved prior to conducting the acoustic reflection survey, and since many of the cores are located a considerable distance off the center line, correlation of all existing core data with the acoustic data proved difficult.

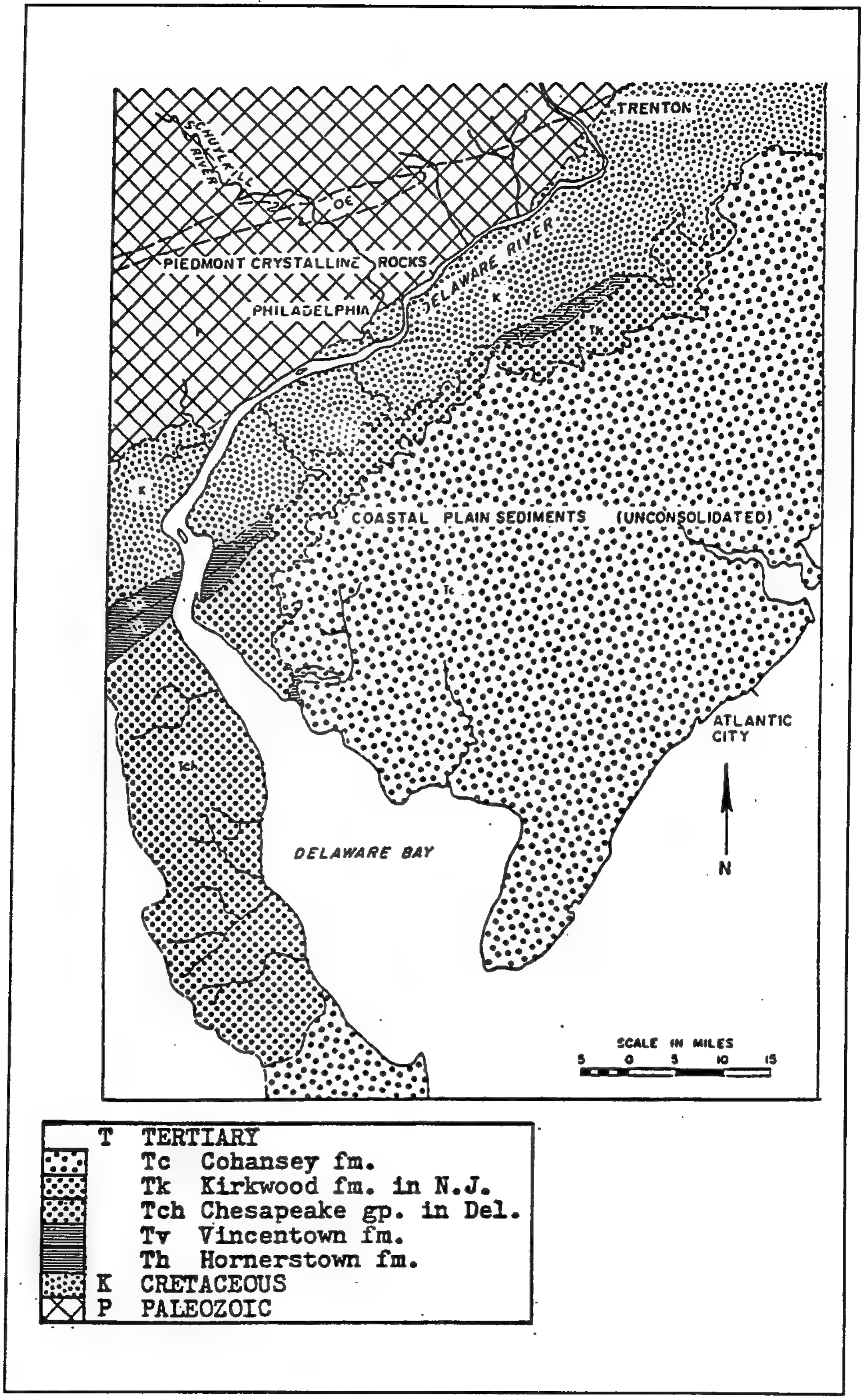


Figure 2. Pre-Pleistocene geology of Delaware, New Jersey, and Pennsylvania (Weil 1977)

2 Geophysical Approach

The technique used to quantitatively assess the characteristics of the sediments along the Delaware Ship Channel is a modified seismic reflection technique that relates the engineering properties of sediments to acoustic impedance by precisely determining the reflection coefficient at each sediment horizon. This Acoustic Impedance (AI) method is discussed in detail by McGee, Ballard, and Caulfield (1995) and in publications listed in the Bibliography. However, it is necessary to briefly describe the method as it applies to the Delaware Ship Channel project. Acoustic theory is discussed only in sufficient detail to enable the reader to understand basic concepts. Specific processing and analysis details will be discussed in Chapter 5.

The AI method is an extension of the techniques developed by Caulfield and Yim (1983) and Caulfield, Caulfield, and Yim (1985) for the identification of subbottom marine sediments. Modelled after Hamilton's approach to geoacoustic modelling of the seafloor (Hamilton 1980), this empirical technique compensates for absorption in each layer as a function of the center frequency of a band-limited seismic trace, corrects for spherical spreading, and uses classical multilayer reflective mathematics to compute reflection coefficients at the sediment horizons. The reflection coefficients are converted to impedances and classified according to established relationships between the acoustic impedance and the geotechnical properties of marine sediments, thereby classifying the lithostratigraphy. Figure 3 illustrates the general processing steps required by the method in practice.

As energy generated from an acoustic source, in the form of a plane wave, arrives at a boundary between two layers of differing material properties, part of the energy will be reflected back toward the surface and part will be transmitted as presented in Figure 4. A portion of the transmitted energy will undergo absorption or attenuation in the layer while the remainder propagates through to the next stratigraphic boundary. According to Snell's law for the case of normal-incidence compressional (P-wave) propagation across the boundary of a horizontally oriented system and for continuity of displacement and stress, the relationship between the incident (A_i), reflected (A_r), and

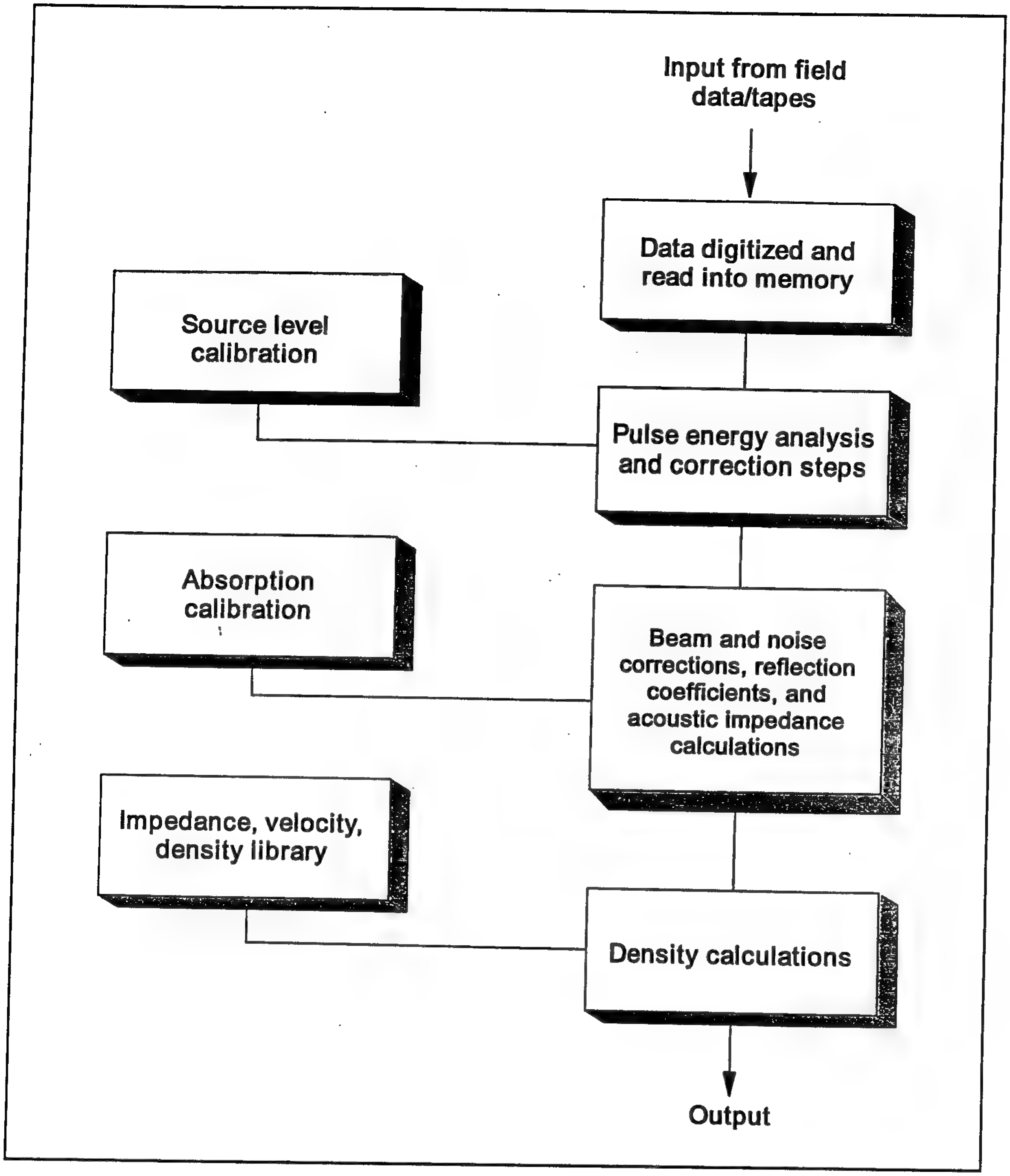


Figure 3. Acoustic Impedance processing flowchart

transmitted (A_t) waves can be expressed as

$$A_i - A_c = \frac{E_2/v_2}{E_1/v_1} A_t \tag{1}$$

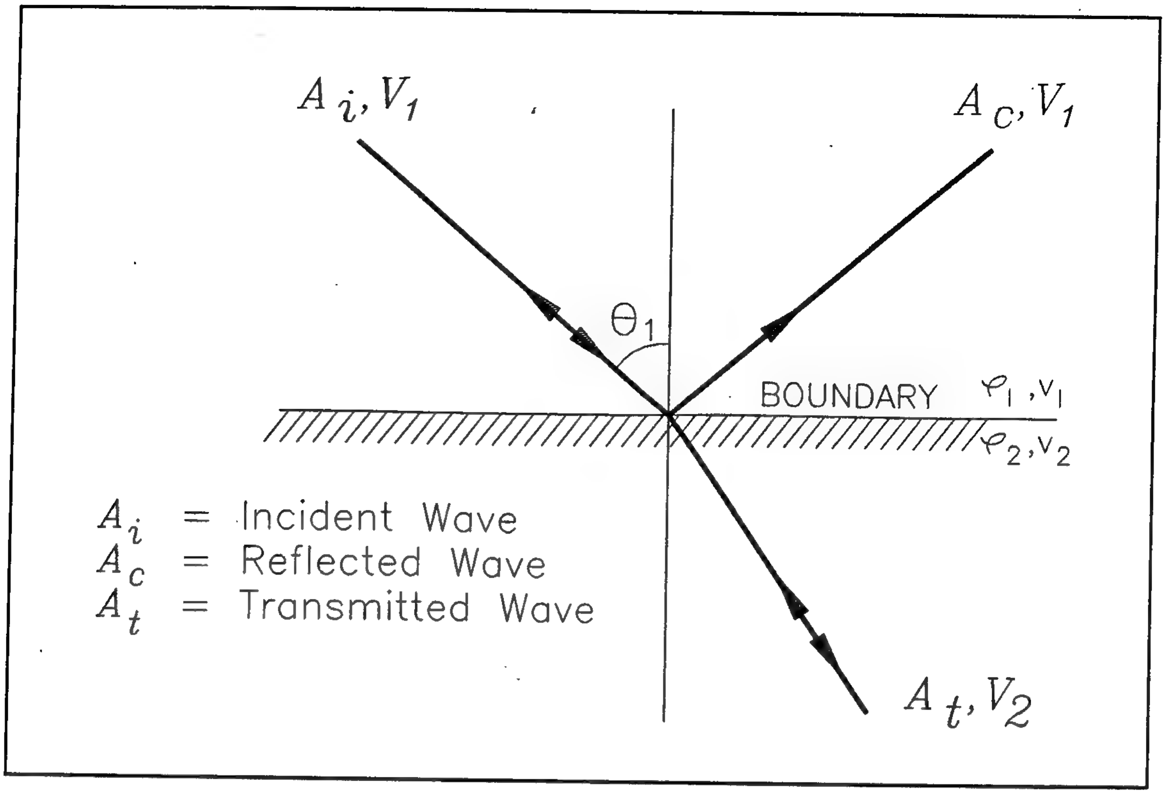


Figure 4. Acoustic wave propagation at a boundary between two interfaces; Snell's law

where E_1 and E_2 are the elastic moduli of media 1 and 2, respectively. For a perfectly elastic medium, $E = \rho v^2$, where ρ is the mass density and v the elastic P-wave velocity. The quantity ρv is called the *acoustic impedance*, Z, of the medium and thus represents the influence of the medium's characteristics on the reflected and transmitted waves. The reflection coefficient, R, is defined as the percentage of the wave's reflected energy. The acoustic impedance and the reflection coefficient are related through the Zoeppritz equation (Zoeppritz 1919) as

$$Z_2 = Z_1 \frac{(1 + R)}{(1 - R)} \tag{2}$$

where Z_1 and Z_2 are the acoustic impedances of the first and second mediums, respectively. This relationship provides a straightforward method for determining acoustic impedance. By knowing the first Z and the succeeding R's, one can then calculate all the acoustic impedances. In this case, the first layer is always seawater, which has a known typical impedance value of 1,550 10^2 g/cm^2 sec. By calculating the remaining R's, the problem is solved.

The relationship between acoustic impedance and specific soil properties has been empirically derived from world averages of measured impedance

versus sediment characteristics (Hamilton, 1970a, b; 1972a, b; 1980; Hamilton and Bachman 1982). Further development of statistical models and algorithms (Caulfield and Yim 1983) establishes relationships between acoustic impedance and soil properties (porosity, bulk density, mean grain size, etc.) for sediments within various natural marine environments and allows the identification and characterization of the subbottom layers from acoustically derived seismic reflection data.

Processing of the seismic data involves determining the precise reflection coefficient at each detectable reflection horizon. This requires that the major losses associated with acoustic wave propagation in a layered sediment environment be properly accounted. These losses include (a) transmission loss due to spherical spreading, (b) transmission through reflectors, and (c) intrinsic absorption within a particular sediment unit. Each of these losses is assessed using processing and analysis tools developed specifically for the AI method. These tools include the Acoustic Core System (Caulfield 1992), the Digital Spectral Analysis System (Caulfield 1991b), the Digital Shallow Seismic Processing and Correlation System (Caulfield 1991a), and in-house WES programs for equipment calibrations and bottom surface analysis using the sonar equations. These programs will be discussed in more detail as they were used in the Delaware Ship Channel study.

Seismic reflection signatures are not universally unique; i.e., several combinations of geologic conditions could conceivably yield similar signal characteristics resulting in similar impedance values. But in a given geologic setting, such as the Delaware Bay, a particular sediment usually has a characteristic, relatively narrow range of impedance values. Therefore, project-specific calibrations are used to relate specific acoustic signatures to respective reflectors. Using calibration procedures incorporating local core data, the acoustic reflection data are processed to yield accurate acoustic impedance values at sediment horizons for the geologic region of interest. The geoacoustic calibrations for the Delaware Ship Channel project are discussed in Chapter 5.

3 Survey and Equipment

Survey

The Delaware Main Channel survey consisted of a single profile line along the center line of the channel beginning at approximately station 530+00 near the mouth of Delaware Bay, as shown in Plate 1, proceeding along a north-westerly course through the bay and up the Delaware River to Philadelphia. The survey ended at the Ben Franklin Bridge at approximately station 13+760. Due to the near 90 miles of survey, the profiles are divided into tangential segments to enhance the data presentation. Specific line numbers, beginning and ending station numbers, and range identifiers are presented in Table 1 and displayed in Plate 1. The sediment profiles are presented according to these line designations. All geographic coordinates are presented in Delaware State Plane, North American Datum of 1983.

Equipment

Survey vessel

The survey was conducted aboard the WES Research Vessel (R/V) *Waterways Explorer*, shown in Figure 5. The following sections describe each piece of equipment.

Navigation and bathymetry

Navigation and horizontal positioning data were obtained using a differential global positioning system (DGPS), specifically a Trimble 4000 SE Mobile GPS receiver. The differential corrections were obtained from the U.S. Coast Guard differential beacon transmitting from the Cape Henlopen Lighthouse at Lewes, DE. The navigation system is rated at providing horizontal accuracy of ±1 to 3 m root mean square (RMS) (68 percent of the time).

Bathymetry was provided by a single 200-kHz high-frequency transducer. The fathometer was attached to the port-side transducer deployment arm as

Table 1
Acoustic Reflection Survey Line Summary

Survey Line Designation	Station Along Center Line		Range Identification
	Begin	End	
DP50	511+695.80	448+120.28	Brandywine
DP51	447+559.80	404+934.21	Miah Maull
DP52	401+173.01	384+219.02	Cross Ledge
SC04A	384+059.27	343+289.27	Liston
SC04B	343+289.27	302+041.81	Liston
SC04C	302+041.81	274.789.71	Liston
SC05	274+556.00	232+219.53	Baker, Reedy Island
SC06A	233+319.51	212.474.76	New Castle, Bulkhead Bar
SC06B	212.474.76	185+919.56	Deepwater Point
SC06C	185+919.56	143+022.66	Cherry Island, Bellevue
SC06D	143+022.66	97+410.64	Marcus Hook, Chester, Eddystone
SC06E	97+432.04	54+864.10	Tinicum, Billingsport, Mifflin
SC06F	54+864.10	41+448.32	Horseshoe, Fisher Point
SC06G	41+448.32	30+101.07	Fisher Point
SC06H	30+101.07	14+685.04	Fisher Point

shown by the schematic in Figure 6. The fathometer was calibrated at the start of each day by the standard bar check method. Water column sound velocity profiles were obtained each day and used in the fathometer calibration. Tide data were obtained by the Philadelphia District from tide gages at Lewes, DE, for the Delaware Bay reach of the survey (lines DP50, DP51, DP52, and SC04), and at Philadelphia for the Delaware River reach (lines SC05 and SC06). All depth data were post-processed with the tide data to arrive at depth elevations referenced to mean lower low water (mllw).

The high-frequency fathometer was inoperable during the surveys of lines SC04, SC05, and SC06. Rigorous calibrations were made during the other surveys to correlate the higher resolution fathometer depth measurements with the low-frequency subbottom profiler depth measurements. The resulting adjustments were applied to the profiler data to obtain bottom depth data.

The navigation, bathymetric, and geophysical equipment were interfaced with the SEATRAC Navigation and Positioning System to record and provide

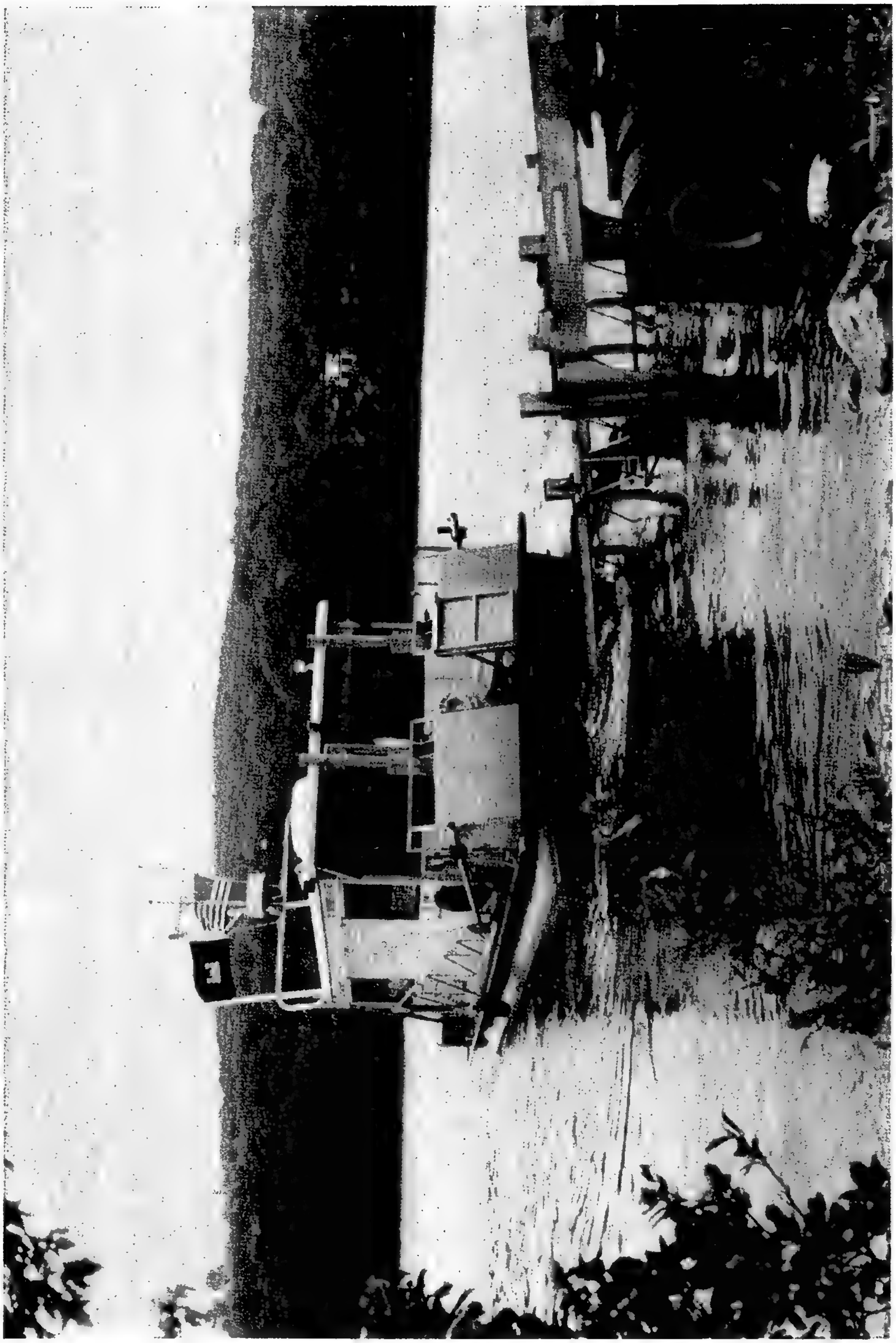


Figure 5. WES Research Vessel *Waterways Explorer*

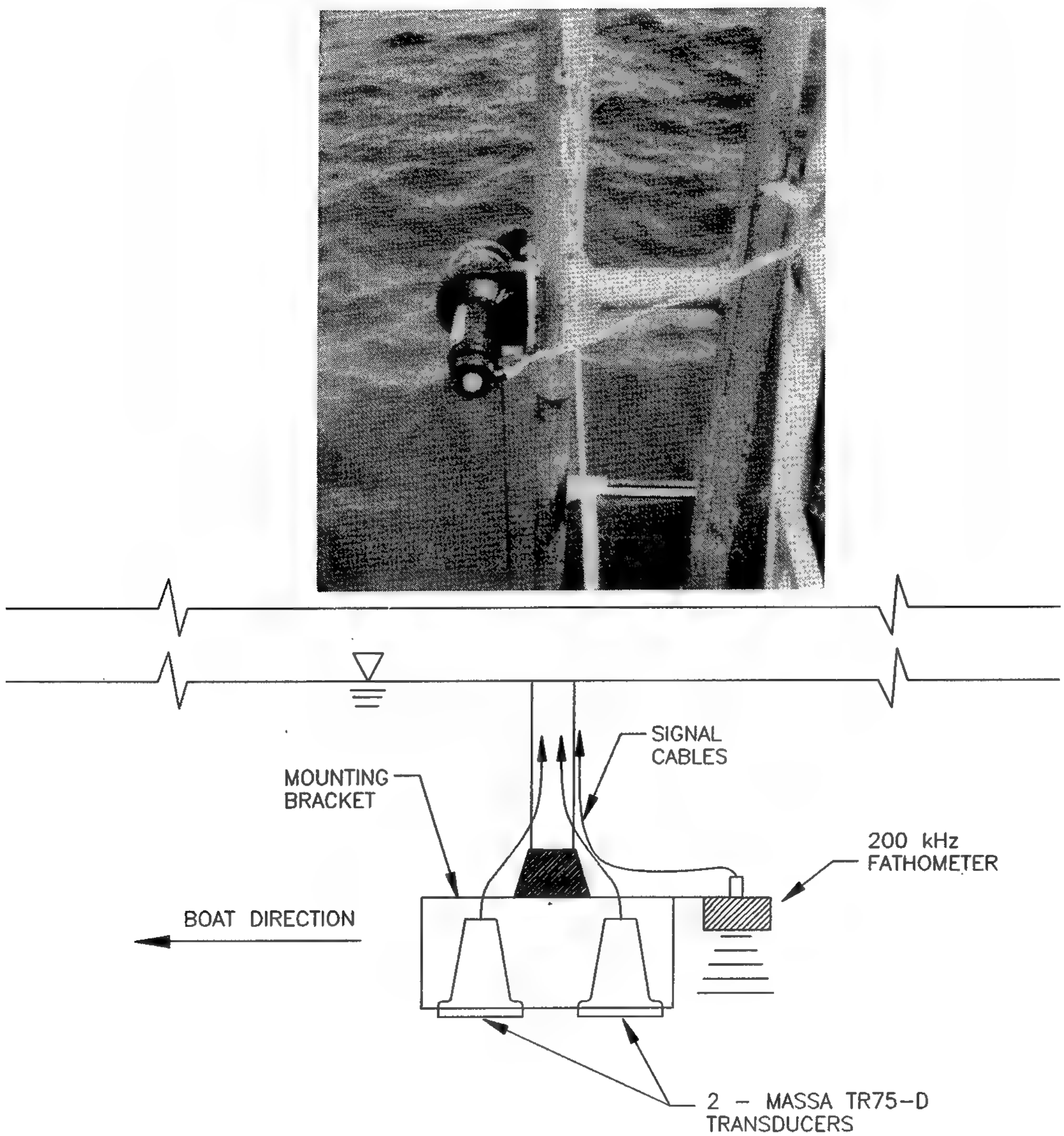


Figure 6. Port-side transducer deployment arm with subbottom profiling receiving array and 200-kHz fathometer

real-time navigation information. This interfacing included outputting the position coordinates and high-frequency bathymetric data directly to the digital seismic data acquisition system providing real-time position logging with the subbottom profile data.

Geophysical equipment

The acoustic subbottom reflection records were generated using a 3.5-kHz high-resolution "pinger" system and a low-frequency 600-Hz "bubble pulse" system. The specific systems used were as follows:

3.5- to 7.0-kHz pinger system. A Datasonics SBP-5000 subbottom profiling system was used during the entirety of the survey. The transmitters were mounted in a towfish rigidly attached to a telescoping arm and deployed through the front deck of the boat as shown in Figure 7. This system allows the transmission of variable-length acoustic pulses (0.2 - 3 msec) of 3.5-, 5.0-, 7.0-, and 12.0-kHz frequencies. Power levels can be varied from 1 to 12 kW. For the Delaware Ship Channel survey, the operating parameters that provided the optimum signal-to-noise (S/N) ratio, resolution, and depth of penetration are shown in the following tabulation:

Power setting, kW	5
Frequency, kHz	3.5
Pulse length, msec	0.2-0.5
Ping rate, sec	0.25

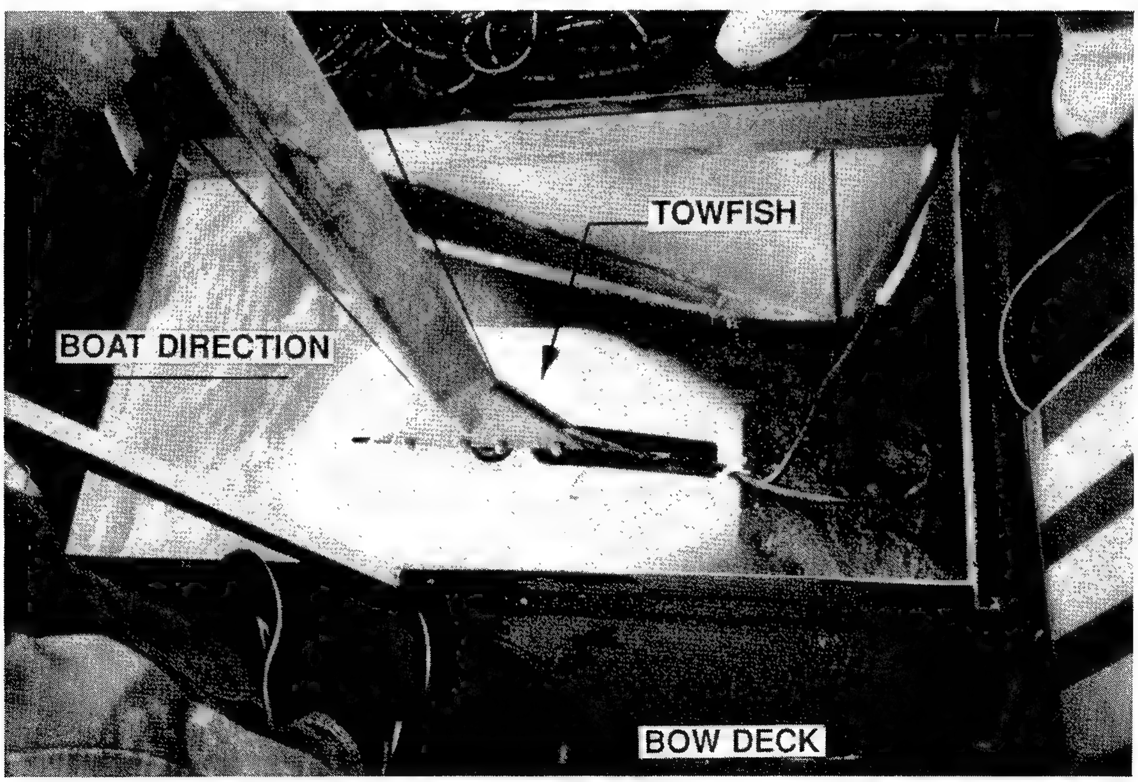


Figure 7. SBP-5000 subbottom profiling towfish. Transducers used as seismic source only

These systems were originally designed to operate in water depths greater than about 50 ft, resulting in configurations employing integrated transmit/receive (T/R) networks to use the same transducers as transmitters as well as receivers. The resulting transducer ringing and coupling create coherent noise keyed to the transmitter timing. In shallow water, less than 30 ft, significant S/N problems arise due to the coherent noise from the transmitter interfering with the first return.

To solve this problem, a receiving array was deployed independently of the transmitter as shown in Figure 6. By decoupling the receiving array from the transmitter and physically separating the transducer, all of the near-field transmitter ringing was eliminated from the bottom reflection, regardless of water depth. This is the standard pinger deployment configuration for the AI method.

Bubble pulse system. The bubble pulser generates a low- to midrange-frequency wavelet, with a frequency content between 400 and 2,000 Hz, with most of the energy between 600 and 900 Hz. Because of the source's low-frequency content, penetration depth in competent materials, such as sands, is significantly greater than the 3.5-kHz system. However, the increased depth of penetration comes at the cost of resolution.

Side-scan sonar. A dual-frequency side-scan sonar (SSS) was operated throughout the survey to provide increased areal bottom coverage. The SSS was operated at 100 kHz and was towed off the starboard side of the bow.

4 Data Processing and Mapping

Acoustic Reflection Data Records

Continuous subbottom profiles of the acoustic reflection amplitudes obtained using the 3.5-kHz pinger system and the bubble pulse system for surveys performed along the Delaware River Main Channel were delivered to the Philadelphia District Project Engineer. The digital data are archived at WES. The records are annotated with digital file numbers, relative depth scales, and all core locations. Figure 8 is a typical color subbottom amplitude record. The color code represents relative reflection amplitudes as displayed by the legend on the figure. The vertical lines along the top portion of the record are the beginning of individual digital data files, recorded continuously during the survey. Files are sorted into six subfiles (0-5) with each subfile containing bins of forty consecutive soundings. These file numbers are used on the final sediment profiles to correlate the calculations with the raw data. Note the top of the graph is not necessarily the water surface, but an assigned water column offset. This offset allows full vertical expansion of the subbottom display, which in this case extends into the subbottom more than 50 ft. Changes in stratigraphy are readily apparent.

Bathymetry

The acoustic reflection data were combined with the position data and the high-frequency bathymetric data, providing accurate determination of both the horizontal and vertical datums. Bottom depths for the subbottom profiles were adjusted to the tide-corrected fathometer depth measurements where possible, since the data provide nearly a 5:1 improvement in resolution over any of the subbottom equipment.

5 Geoacoustic Modelling

Using calibration procedures for data with high S/N ratios, seismic reflection data are processed to provide estimates of the density, mean grain size, and soil type of bottom and subbottom sediments. Calibrations are performed by correlating acoustic impedance values calculated from the seismic reflection data at a sample location with the measured information (density, mean grain size, etc.) at that location. Experience to date has shown that calibrations made at a few locations within a geologic region provide the necessary shallow seismic parameters to accurately calibrate and describe the entire region.[1] Calibration of the acoustic reflection data for the Delaware River Main Channel survey is briefly described in the following paragraphs.

Equipment Calibration: Sources and Receivers

Sonar equations

The geoacoustic parameter calibration procedure begins by determining the total acoustic energy incident at the bottom surface. This basically involves determining the precise reflection coefficient for the first reflector (bottom surface) and its associated acoustic bottom loss for a given sediment. Since the sound velocity of water and its density can be readily measured, the absolute impedance of the water can be calculated. Knowledge of the reflection coefficient, which is completely independent of frequency, from the water-bottom interface allows direct computation of the absolute impedance of the first layer of the bottom. The total energy produced by the source, or source wavelet, must be known absolutely. This is accomplished through use of a calibration hydrophone allowing determination of source level (SL) and the transmission losses associated with underwater acoustic wave propagation through the *sonar equations*. The sonar equations, discussed thoroughly by Urick (1983), describe the quantitative effects on sonar equipment created by the many phenomena peculiar to underwater sound production. These

[1] R. G. McGee. (1991). "Subbottom hydro-acoustic survey of Gulfport Ship Channel," Memorandum for Record, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

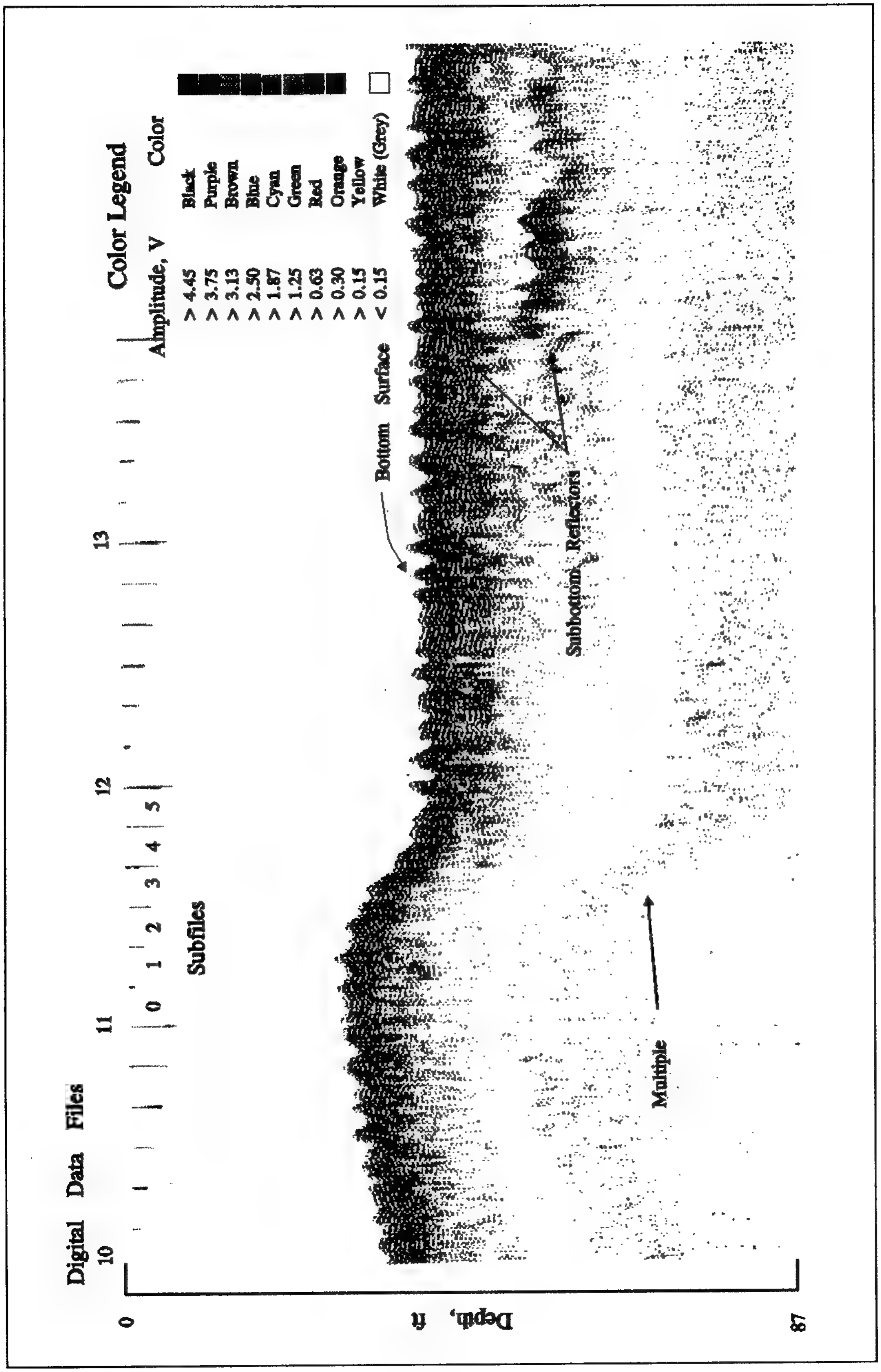


Figure 8. Typical color subbottom amplitude record

equations are both design and prediction tools for underwater sound applications and relate the effects of the medium, the target, and the equipment. The general sonar equation is given as follows:

$$S_R = SL - N_w - N_{hyd} + N_A + DI + BL \tag{3}$$

where

S_R = bottom reflection energy at receiver, db

SL = total energy of source, db

N_w = transmission loss due to spherical spreading along the path of propagation, db = $20 \times \log_{10}$ (range, meters)

N_{hyd} = receiver sensitivity, db

N_A = amplifier gain, db

DI = directivity index of receiving array, db (function of transducer beam pattern)

BL = bottom loss, db = $20 \log_{10}(R)$

The effect of temperature on sound speed is considered neglible for the frequencies of interest (<20 kHz) and the relatively short propagation paths (<200 ft) of the acoustic wave fronts and is therefore ignored in the sonar equation.

Figure 9 is a detailed depiction of the physical elements in a normal calibration and bottom reflection sonar equation solution case. The N_A value includes all preamplifiers and amplifiers and is obtained from the electrical calibration of the receiving equipment. The calibration hydrophone receiver sensitivity N_{hydc} is available from manufacturers of the hydrophone and should be traced to the American National Standards Institute (ANSI) Standard (Acoustical Society of America 1988). The receiving array sensitivity N_{hydr} may also be available from the manufacturer or can be easily calibrated in the field using the calibration hydrophone and an alternate form of the sonar equation. This procedure will be discussed in detail a little later in the report.

Directivity index

The DI is a function of the beam pattern of the transducer array and is an indication of the amount of the total signal the hydrophone is permitted by its sensitivity pattern. The higher the DI, the more discriminating the hydrophone is against signals arriving from directions other than along the acoustic

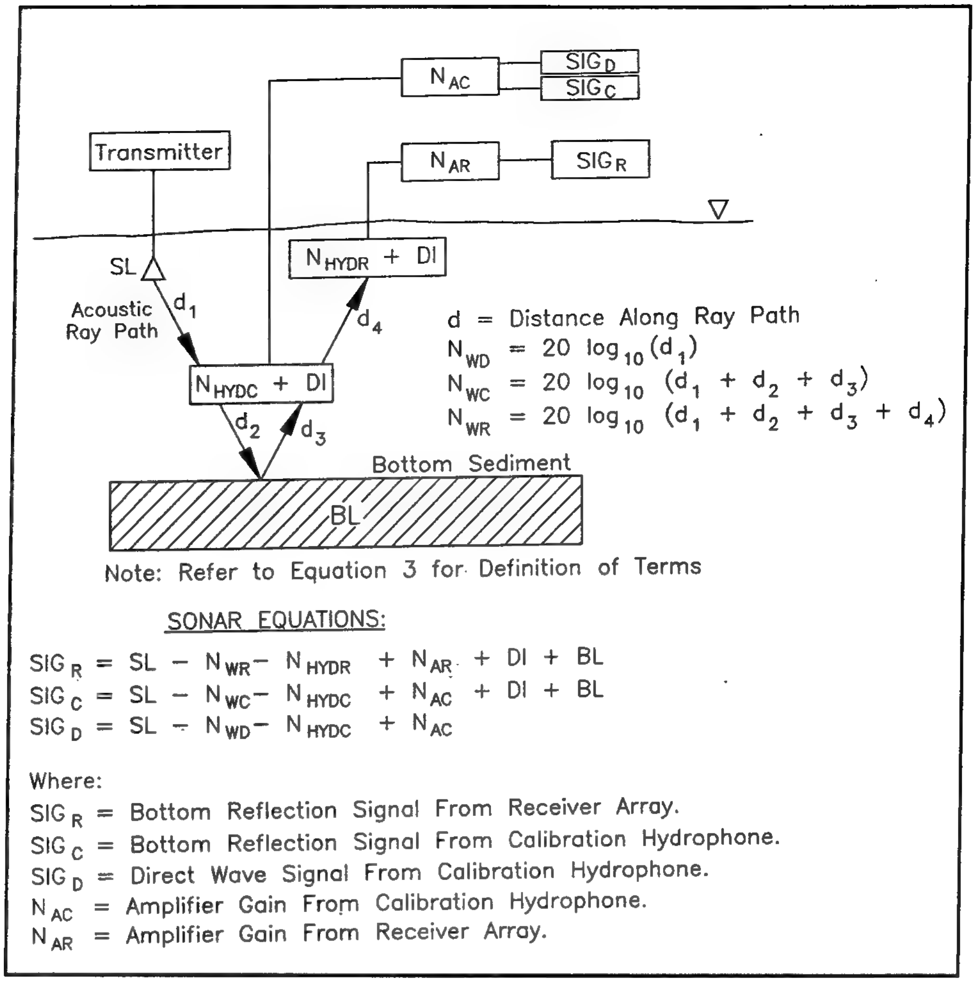


Figure 9. Elements in acoustic calibration and bottom reflection sonar equation solution

axis. Figure 10a presents the directional pattern of the MASSA Model TR75-A transducer receiving array used with the pinger system. Because the transmitter and receivers are horizontally offset, as explained in Chapter 3, the *DI* can possibly become a significant parameter due to the reflection angles along the path of propagation. Figure 10b presents the equipment geometry for the R/V *Waterways Explorer* and its effect on directivity. Figure 10c, the *DI* correction versus water depth for application in the sonar equation, shows that for water depths greater than 40 ft, the *DI* due to the path of propagation is zero and therefore not a factor. This is the case for the entire Main Channel survey. However, directivity in the form of reflected waves travelling either directly at or away from the receiving array will drastically affect the reflectivity analysis. Such would be the case when sounding in areas with irregular bottom topography, i.e., sand waves, side slopes of channels, trenches, etc. Acoustic analysis is limited in these areas.

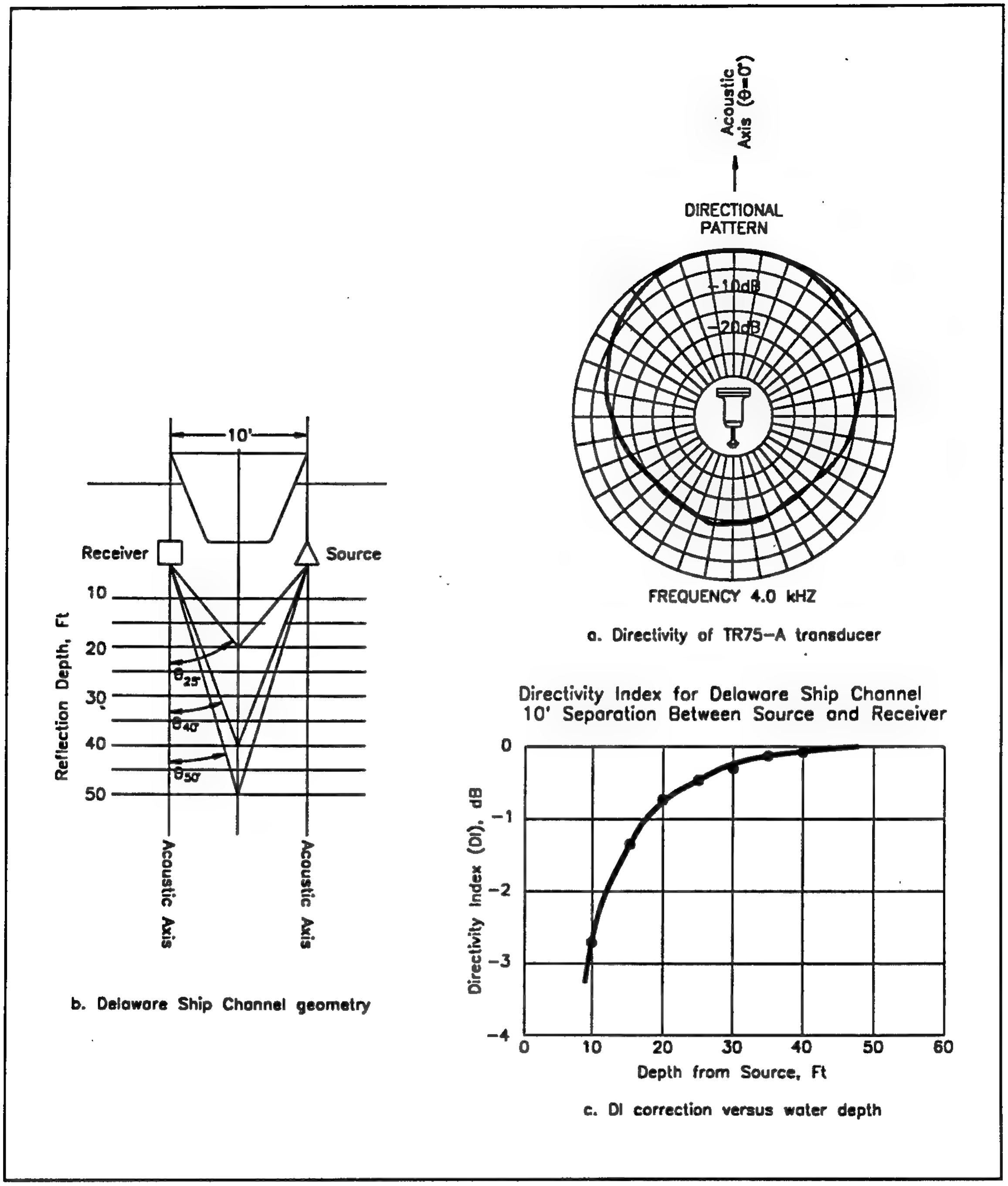


Figure 10. Computation of *DI* versus water depth and transducer separation

Source level (SL) calibration

The first step in the calibration process is to determine the absolute source level. This information is available from the manufacturers of some sonars. Unfortunately, many seismic systems do not have this information readily available; and even if they did, the field operating conditions vary to such an extent that the published levels are not sufficient for precise reflection computations.

The direct wave calibration of the sonar source level is accomplished by writing the sonar equation for the measurement of the direct wave via the calibration hydrophone as follows:

$$S_D = SL - N_{wdir} - N_{hydc} + N_A \tag{4}$$

where

S_D = direct wave signal level, db

N_{wdir} = transmission loss between source and cal phone, db

All the terms in Equation 4, except *SL*, are either absolutely known or directly measured. Therefore, solving for *SL* determines the absolute source level. Figure 11 presents a typical seismic system calibration data plot. This single data record contains all the field data required to completely calibrate all aspects of the equipment operations and provide calibration data for the surface sediment impedance. The *SL* calibration is performed using the data between file number 0002 and 0004 where variations in amplifier gain and hydrophone range are occurring.

An example SL calculation using the sonar equations is shown by Figures 12 and 13. Figure 12 is the calibration data record for this example (data format similar to Figure 11). Figure 13 presents the sonar equation computations and statistical evaluation of forty consecutive soundings from a digital subfile of the calibration data. This analysis has been accomplished at many sites throughout the country for the sound source used during this survey. The following tabulation summarizes the calibrated source characteristics for the pinger system as operated during the survey:

Pulse Length, msec	Output Power, kW	SL, db[1] (Peak Detect)	SL, db (RMS Energy)	Receive Sensitivity db
0.2	5.0	106	100	-70
0.5	5.0	112	106	-70

[1] Calibration levels are in db relative to 1 dyne/cm^2.

Receiving hydrophone sensitivity calibration

As with the source level, the array sensitivity of the receiving hydrophones N_{hydc} must be absolutely known. The field calibration is performed by comparing the signal levels of the receiving array with the calibration hydrophone over the same bottom condition. The calibration hydrophone is placed in the immediate vicinity of the receiving array at the same depth. The sonar

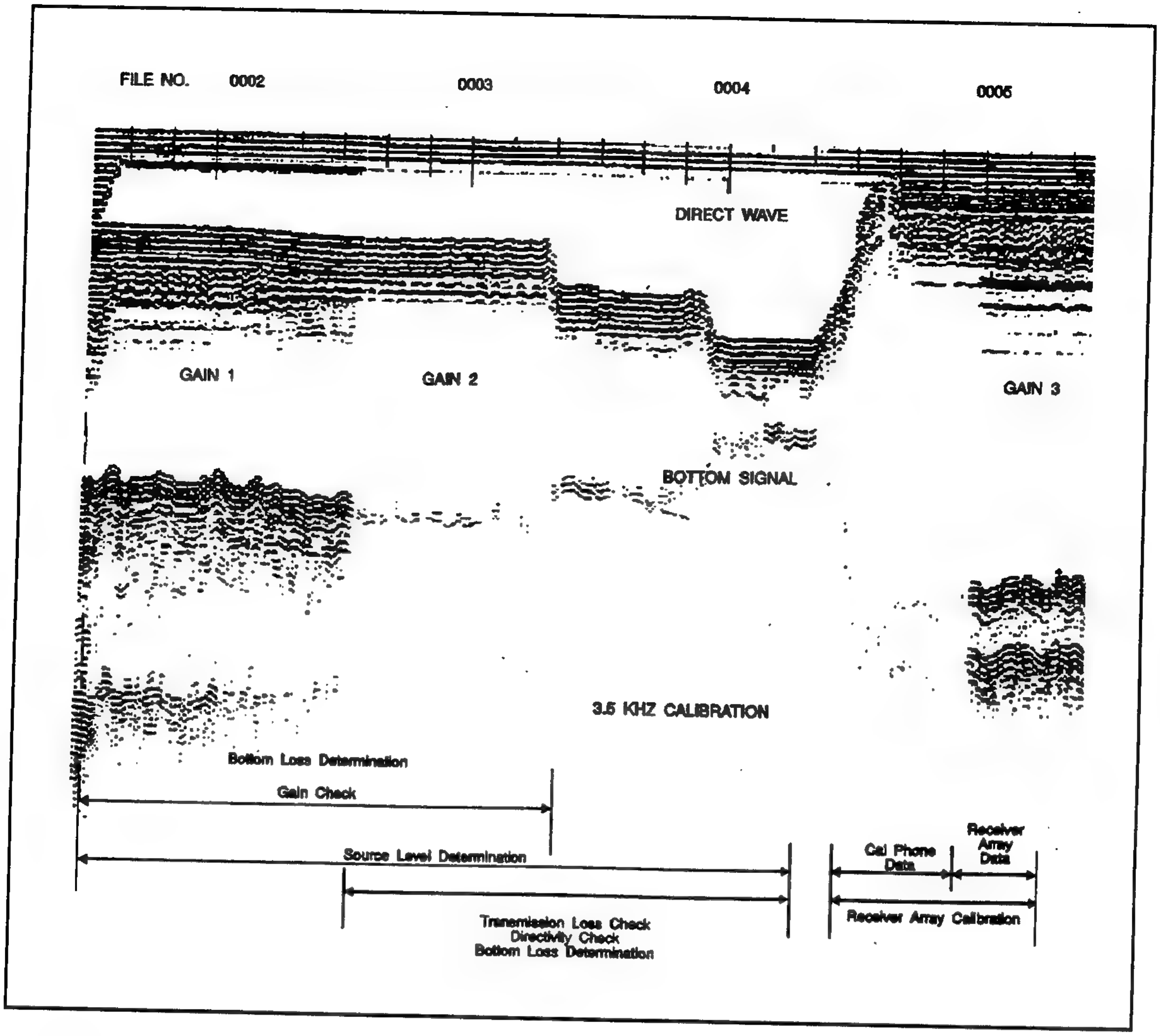


Figure 11. Typical acoustic calibration record

equation is designed to solve for N_{hydr} as follows:

$$N_{hydr} = N_{hydc} + S_{Rr} - S_{Rc} - N_{Ar} + N_{Ac} \tag{5}$$

where S_{Rr}, N_{Ar}, and S_{Rc}, N_{Ac} are the receive signals and amplifier gains for the receiving array and calibration hydrophone, respectively. The N_{hydr} for the array used for the Delaware Main Channel survey has been calculated to be -70 db relative to 1 dyne/cm^2 as shown in the preceding tabulation.

Determination of Bottom Loss and Surface Reflection Coefficient

The bottom surface characteristics are evaluated through the sonar equation

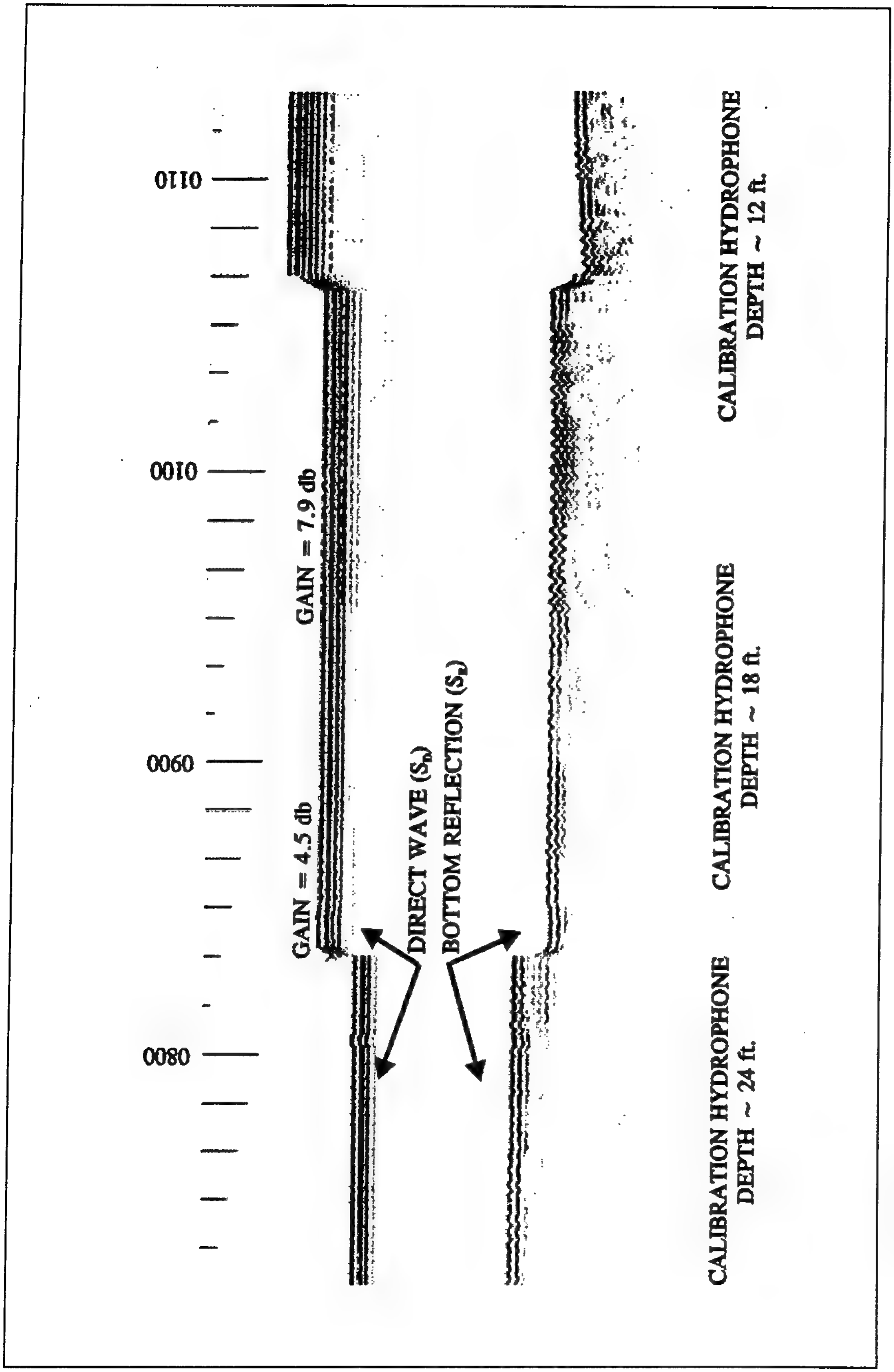
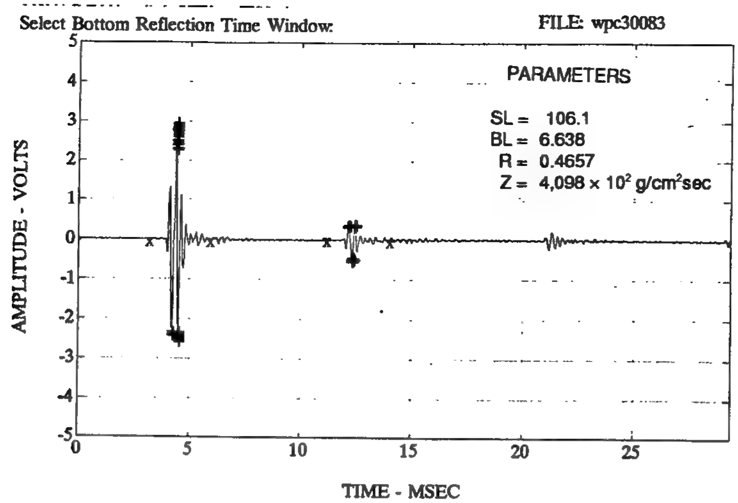


Figure 12. Calibration record: bottom loss, source level, and directivity determination



CALIBRATION: SL & BL FROM CAL DATA
FILE: wpc30083

Amplifier Gain (dB):	4.50 dB
Hydrophone Sensitivity:	-86.00 dB
Range of Direct Signal:	6.69 meters
Range of Bottom Reflection:	18.43 meters

Trace #	SIGdir	SIGbot	SLnet	BLnet
1	7.79	-7.21	105.79	6.14
2	7.65	-7.24	105.69	6.03
3	7.67	-7.44	105.70	6.28
4	7.63	-7.46	105.67	6.26
5	8.32	-7.51	106.03	6.71
6	8.11	-7.29	106.15	6.61
7	8.25	-7.66	106.29	7.11
8	8.43	-7.41	106.47	7.04
9	8.47	-7.49	106.27	6.90
10	8.31	-7.34	106.35	6.82
11	7.85	-7.59	105.89	6.69
12	7.46	-7.49	105.50	6.19
13	7.77	-7.90	105.77	6.78
14	7.71	-8.25	105.42	6.80
15	7.71	-7.44	105.75	6.34
16	8.34	-7.36	106.38	7.01
17	8.36	-7.14	106.40	6.81
18	8.49	-7.29	106.53	7.06
19	8.40	-7.95	106.44	7.63
20	8.21	-7.31	106.25	6.77
21	8.08	-7.31	106.12	6.57
22	7.45	-7.61	105.49	6.23
23	8.26	-7.44	105.97	6.65
24	7.69	-7.39	105.73	6.36
25	7.95	-7.85	105.99	6.99
26	7.90	-7.26	105.94	6.48
27	8.36	-7.12	106.40	6.79
28	8.43	-6.90	106.47	6.53
29	8.46	-7.00	106.50	6.62
30	8.43	-6.90	106.47	6.59
31	8.20	-7.51	106.24	6.93
32	8.00	-7.54	106.04	6.79
33	7.93	-7.66	105.97	6.77
34	7.80	-7.07	105.84	6.15
35	7.91	-7.44	105.95	6.54
36	7.72	-7.44	105.76	6.46
37	8.21	-7.49	106.24	6.88
38	8.06	-7.07	106.10	6.41
39	8.28	-6.88	106.31	6.44
40	8.39	-6.72	106.43	6.39
Max	8.49	-6.72	106.53	7.63
Mean	8.07	-7.38	106.07	6.64
Min	7.45	-8.25	105.42	6.03
Std	0.31	0.31	0.32	0.32

Figure 13. SL calibration data

by rearranging Equation 3 to solve for *BL* as follows:

$$BL = S_R + N_{hyd} - SL + N_w - N_A - DI \tag{6}$$

Since all terms on the right side of the equation are now known, *BL*, and therefore the surface reflection coefficient ($BL = 20 \log_{10} R$) and acoustic impedance (Equation 2), can be readily determined. If the desired result is an assessment of the bottom surface characteristics, the acoustic solution is complete. All that remains is the correlation of the acoustic parameters with the physical sediment properties. Correlations of *BL* and specific soil properties are presented in the "Geoacoustic Relationships" section of this chapter.

Physical Sediment Analysis

The vibracore drilling logs and sediment gradation curves from the 1991 exploration program are provided in Appendix A. The geotechnical testing results provided to WES of selected sections of each 1991 core (DRV-1 through -29) included seive analysis down to the No. 200 seive and sediment classification according to the Unified Soil Classification System (USCS). Further processing of the data was conducted to characterize the sediments in a manner suitable for correlation with acoustic data. This included conversion of grain sizes in millimeters to the ϕ-scale and computation of grain size parameters and grain distributions. Mean grain size was computed as the average of the D_{84}, D_{50}, and D_{16} sizes, and the sediment distributions were grouped as percentages of gravels, sands, and fines. Table 2 presents an overview of specific engineering properties of each sediment sample collected.

In addition to the most recent cores, core logs from much earlier sampling programs were used, particularly for the study area north of the Liston Range. These logs proved quite useful in defining zones of organic-rich sediments not sufficiently sampled in the 1991 program.

Geoacoustic Relationships

The Delaware River Main Channel sediment characterization used to relate density, mean grain size, and soil type is summarized in Table 3. In general, the categories established delineate the predominantly clay, silt, and sand sediment types. However, sediment mixtures such as clayey sands and silty sands can exhibit uncharacteristically high or low density values. Also, the mean grain size parameter may not always completely describe actual sediment conditions. Factors such as sorting and grain size variability are not necessarily reflected in the mean grain size parameter. The present state of geoacoustic technology really does not allow for the microdelineation of all

Table 2
Geoacoustic Survey Core Analysis

Core ID	No.	Core Elevation ft NGVD	Sample Depth, ft	Grain Size, mm D_{84}	D_{50}	D_{16}	Mean	Distribution, % Gravel	Sand	Fines	Laboratory Classification, USCS
DRV-1	1	47.5	0-1	1.02	0.425	0.3	0.645	4	93.5	2.5	SP
	2		1-4.3	40	21	5	22	84	16	0	GW
	3		6.3-10	1.1	0.607	0.325	0.698	0	98.6	1.4	SP
	4		10-14.7	0.7	0.425	0.265	0.463	11	93.5	5.5	SP
	5		14-18	1.1	0.401	0.295	0.597	5	91.5	3.5	SP
DRV-2	1	48.7	1-2.3	0.925	0.285	0	0.403	0.05	71.5	28.5	SM-SC
	2		2.3-4.4	0.7	0.425	0.315	0.48	3.5	95.5	1	SP
	3		4.4-8.2	10.1	2.805	0.301	4.402	35	59	6	SM-SC
	4		8.8-10	10.205	0.509	0.301	3.672	22	74	4	SP
	5		12.4-16	0.109	0	0	0.036	0	46	54	ML
DRV-3	1	49	0.4-5	11.05	4.905	0.309	5.421	50	49	1	GP
	2		7.9-9.1	1.605	0.609	0.325	0.846	10.05	87.5	2	SP
	3		11-15	11.8	6.905	1	6.568	60	39.5	0.5	GW
	4		15-19.5	6.08	1.2	0.601	2.627	29	68	3	SP
DRV-4		46	.7-2.6	0.207	0.115	0	0.107	0.5	60.95	39	SM-SC
DRV-5		49.3	0-1.7	0.795	0.405	0.202	0.467	0	95.5	0.5	SP
DRV-6	1	51	0-5	1.405	0.705	0.0702	0.727	0	88	12	SM-SC
	2		7.1-10	0.308	0.206	0	0.171	0	60.5	39.5	SM-SC
	3		11.7-15	10.805	3	0.2805	4.695	45	51.5	3.5	SP
	4		11.6-19	11.205	2.07	0.302	4.526	10.05	86.95	4	SP
DRV-7		49.8	1.3-3.7	0.395	0.195	0	0.197	0	69	31	SM-SC
DRV-8	1	48.5	5-10	0.825	0.105	0	0.31	0	51.5	48.5	SM-SC
	2		10-15	0.4	0	0	0.133	0	36	64	CL
	3		15-19	10.08	3	0	4.36	41	33	26	GM-GC
DRV-9	1	48	0-5	0.9	0.106	0	0.335	0	51	49	SM-SC
	2		5.5-11	0.6	0	0	0.2	0	43	57	ML
	3		12.3-16	1.105	0.203	0	0.436	1	60.5	38.5	SM-SC

(Continued)

(Sheet 1 of 4)

Table 2 (Continued)											
				Grain Size, mm				Distribution, %			
Core ID	No.	Core Elevation ft NGVD	Sample Depth, ft	D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Fines	Laboratory Classification, USCS
DRV-10	1	48.7	0-5	1.01	0.225	0	0.412	0	59	41	SM-SC
	2		5-10	0.808	0.201	0	0.336	0	68.5	31.5	SM-SC
	3		13.3-15	0.695	0.195	0	0.297	0	79.5	20.5	SM-SC
DRV-11	1	50	0-5	1.02	0.101	0	0.374	0	78	22	SM-SC
	2		5-10	1.205	0.307	0	0.504	0	70	30	SM-SC
DRV-11	3		10-15	1.101	0.108	0	0.403	0	59	41	SM-SC
	4		15-19	0.9	0.2	0	0.367	0	75.5	24.5	SM-SC
DRV-12	1	44.5	0-5	1.01	0.107	0	0.372	0	58.5	41.5	SM-SC
	2		8.9-10	1.03	0.425	0	0.485	5	66	29	SM-SC
	3		10-15	1.02	0.225	0	0.415	0	61	34	SM-SC
	4		15-17	0.808	0	0	0.269	0	45.1	54.9	ML
DRV-13	1	53.0	0-5	1.02	0.407	0	0.476	0	79	21	SM-SC
	2		5-9.25	0	0	0	0	0	14	86	CH
	3		10-12.4	0.7	0.206	0.107	0.338	2	93	5	SP
	4		12.4-15	10.205	4.0	0.5	4.902	47.5	51.5	1	SP
	5		17.1-20	0.4	0.203	0.1	0.234	0	87	13	SM-SC
DRV-14	1	45.5	0-5	1.01	0.207	0	0.407	0	64	36	SM-SC
	2		7.4-10	0	0	0	0	0	14	86	MH
	3		12.2-15	0.201	0	0	0.067	0	25	75	CL
	4		15-20	0.5	0.1	0	0.2	0	53	47	SM-SC
DRV-15	1	46.8	0-3.4	1	0.408	0.301	0.570	1	97	2	SP
	2		3.4-5	10	1.08	0.402	3.827	31	68	1	SP
	3		7.5-9.2	0.308	0.225	0.102	0.212	1.05	88.95	10	SP
	4		10.8-14	2.01	0.908	0.5	1.39	7	90	3	SP
DRV-16	1	39.2	0-5	0.225	0.101	0	0.109	0	68	32	SM-SC
	2		5-10	0.207	0	0	0.069	0	37	63	ML
	3		10-15	0.7	0.103	0	0.268	0	64	36	SM-SC
	4		15-19	0.2	0	0	0.067	2	31	67	ML

(Sheet 2 of 4)

Table 2 (Continued)											
				Grain Size, mm				Distribution, %			
Core ID	No.	Core Elevation ft NGVD	Sample Depth, ft	D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Fines	Laboratory Classification, USCS
DRV-17	1	46.0	0-1.2	11	2	0.301	4.434	38	60	2	SP
	2		1.1-2.4	0.4	0.101	0	0.167	0	58.5	41.2	SM-SC
	3		2.4-3.7	0.302	0.201	0.09	0.198	0	87	13	SM-SC
	4		3.7-10	0.425	0.208	0	0.211	0	71	29	SM-SC
DRV-18	1	46.0	0-4.1	0.5	0.301	0.125	0.309	0.05	96.95	3	SP
	2		5.1-9.1	10.09	7	0.502	5.864	52	46	2	GP
	3		9.1-10	0.402	0.325	0.102	0.276	1	87	12	SW
	4		10.7-11.7	2	0.425	0	0.808	21	60	19	MC-SC
DRV-19	1	49.0	0-2.1	0.308	0.201	0.09	0.108	2	78	19	SM-SC
	2		2.1-5	0.825	0.101	0	0.309	0	52	48	SM-SC
	3		5-10	0.705	0.306	0	0.337	2	81	17	SM-SC
	4		11-15	0.501	0.207	0	0.236	3	63	34	SM-SC
	5		15.7-16.7	12.07	0.401	0.2	4.224	26	68	6	SP
DRV-20	1	48.5	1.1-5	0.608	0.325	0.202	0.378	3	93	7	SP
	2		8.1-10	0.306	0.225	0.101	0.211	0	86	14	SM-SC
	3		13.4-15	0.5	0.202	0	0.234	0	78	22	SM-SC
	4		15.9-20	0.602	0.3	0.2	0.367	0	94.5	5.5	SP
DRV-21	1	48.0	0-5	8	0.6	0.301	2.967	18	80	2	SP
	2		4.3-5.7	0.8	0.406	0.207	0.471	1	97	2	SP
	3		5.7-10	0.5	0.201	0	0.234	0	81	19	SM-SC
	4		10-14	0.401	0.202	0	0.201	0	71	29	SM-SC
DRV-22	1	48.0	0-1	10.02	4.02	0.825	4.955	40	59.5	0.5	SP
	2		1.6-5.3	0.9	0	0	0.3	0	37	63	ML
	3		7-9.2	0.2	0	0	0.067	0	24	76	CH
DRV-23	1	51.0	0-3.7	0.6	0.301	0.108	0.336	0.5	93.5	6	SP
	2		3.7-5	10.06	7	0.502	5.854	57	41	2	GP
	3		8.3-9.2	0.102	0	0	0.034	0	22	78	CL
	4		9.2-13	0.302	0.101	0	0.134	0	61.5	38.5	SM-SC

(Sheet 3 of 4)

Table 2 (Concluded)											
				Grain Size, mm				Distribution, %			
Core ID	No.	Core Elevation ft NGVD	Sample Depth, ft	D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Fines	Laboratory Classification, USCS
DRV-24	1	50.5	0-3	0.6	0.301	0.225	0.375	1	97	2	SP
	2		5-10	1.01	0.5	0.206	0.572	2	97	1	SP
	3		11.6-13.6	0.7	0.401	0.207	0.436	0	98	2	SP
	4		13.6-15.6	9.03	1	0.307	3.446	23	74	3	SP
DRV-25	1	47.0	0-5	1.01	0.509	0.301	0.607	1	96	3	SP
	2		5-7.8	0.8	0.401	0.207	0.469	1	94	5	SP
	3		7.8-10	0.407	0.302	0.202	0.304	0	96	4	SP
	4		10-15	0.7	0.401	0.207	0.436	0	92	8	SP
	5		16.7-17.5	11.25	1.07	0.407	4.242	38	61	1	SP
	6		17.5-20	0.09	0	0	0.03	0	16.5	83.5	ML
DRV-26	1	49.5	0-5	0.4	0.201	0.102	0.234	1	94.5	5.5	SP
	2		8.3-10	0.7	0.301	0.107	0.396	3	94	5	SP
	3		12-14.6	0.225	0	0	0.075	0	41	56	ML
	4		14.6-16	0.3	0.103	0	0.134	0	74.5	25.5	SM-SC
DRV-27	1	50.0	0-8	0.501	0.207	0.2	0.303	0	97	3	SP
	2		1.8-5	0.202	0.103	0.101	0.135	0	92	8	SP
	3		7.2-10	0.6	0.201	0	0.267	0	71	29	SM-SC
	4		11.3-15	0.408	0.301	0.125	0.278	0	95	5	SP
	5		15-16.5	0.4	0.3	0.125	0.275	0	96	4	SP
	6		16.4-18	0.402	0.309	0.125	0.279	0	93	7	SP
DRV-28	1	47.0	1-5	0.525	0.107	0.115	0.249	2	97	1	SP
	2		5-10	0.103	0.2	0.09	0.1	0	86	14	SM-SC
	3		10-16.5	0.201	0.09	0	0.097	0	56	44	SM-SC
DRV-29	1	47.0	0-1.8	0.206	0.104	0.101	0.137	0	92	8	SP
	2		1.9-5	0.203	0.103	0.101	0.137	1	90	9	SP
	3		7.7-10	0.225	0.106	0.115	0.142	0	93.5	6.5	SP
	4		10.4-15	0.201	0.104	0.115	0.14	0	96	4	SP
	5		15-20	0.301	0.106	0.115	0.174	1	92	7	SP

(Sheet 4 of 4)

Table 3
Sediment Description

Density g/cm^3	Mean Grain Size ϕ_m	Basic Sediment Description
1.0 - 1.4	Outside model boundary	Soft muds, clays
1.4 - 1.6	> 4	Clays, silts, sandy silts
1.6 - 1.8	4 - 2.2	Clayey sands, silty sands
1.8 - 2.0	2.2 - 1.2	Silty sands, fine sands
2.0 - 2.2	1.2 - 0	Medium sands
2.2 - 2.4	> 0	Coarse sands and gravels
> 2.4	N/A	Stiff clays, rock

grain size parameters. It does, as will be shown, provide good characterization of the general nature of the insonified sediment structure.

Impedance versus soil properties

No laboratory measurements of density were performed on the core samples, which, as stated in Chapter 1, were collected 3 years prior to this study. Therefore, the geoacoustic model relating impedance to density was taken from a previously established database by Hamilton and Bachman (1982) (Figure 14). This model has been successfully used in lieu of site-specific in situ density/acoustic correlations as shown by Figure 15 and discussed by McGee, Ballard, and Caulfield (1995). It has been shown (McGee, Ballard, and Caulfield 1995) that for the case of naturally occurring sediments, i.e., in a marine environment and with similar sedimentological conditions, density estimates based on acoustic impedance can be estimated within ± 10 percent. Had density measurements been available from reasonably undisturbed sediment samples, the accuracy of the density estimates could be improved to about ± 5 percent; however, the stated ± 10 percent should be sufficient to meet the stated objectives of this study, i.e., characterization of sediments pertaining to removal by dredging.

Impedance versus mean grain size is modelled according to the geoacoustic relationship developed for the Delaware Coast AI study (McGee 1995). Figure 16 presents the Delaware Coast grain size model with data points from core sites along the Delaware Main Channel and from the New Jersey coast.

Table 4 summarizes acoustic response characteristics of surface sediment data collected at various core sites along the ship channel. Listed are the

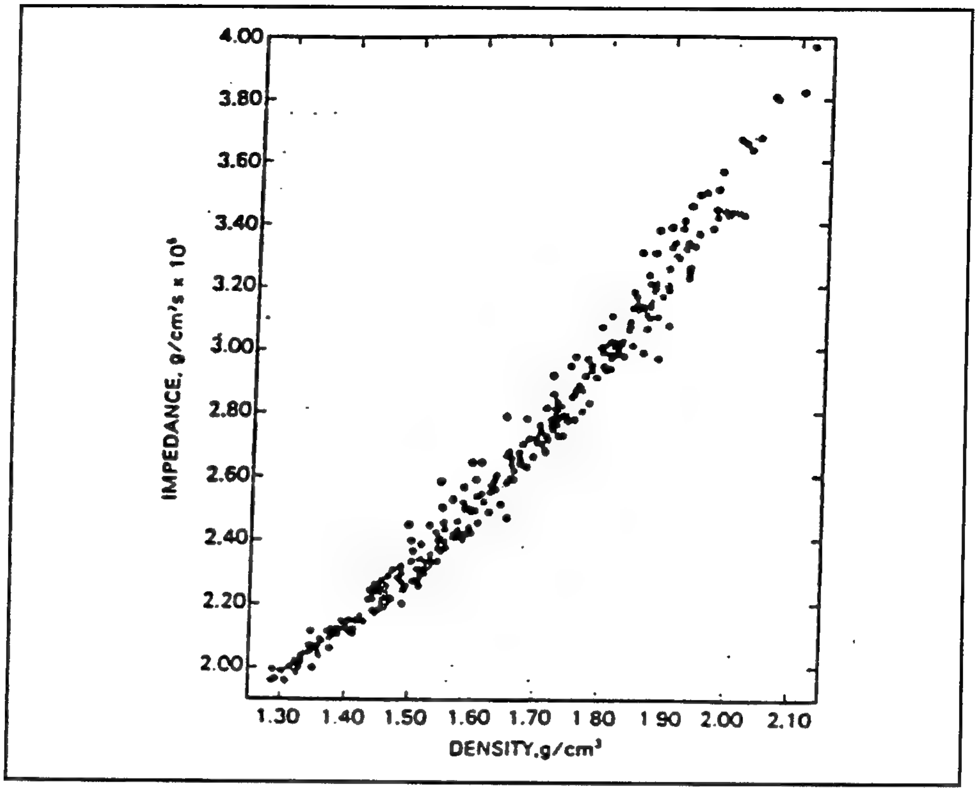


Figure 14. Density versus impedance (continental terrace, shelf, and slope) (from Hamilton and Bachman 1982)

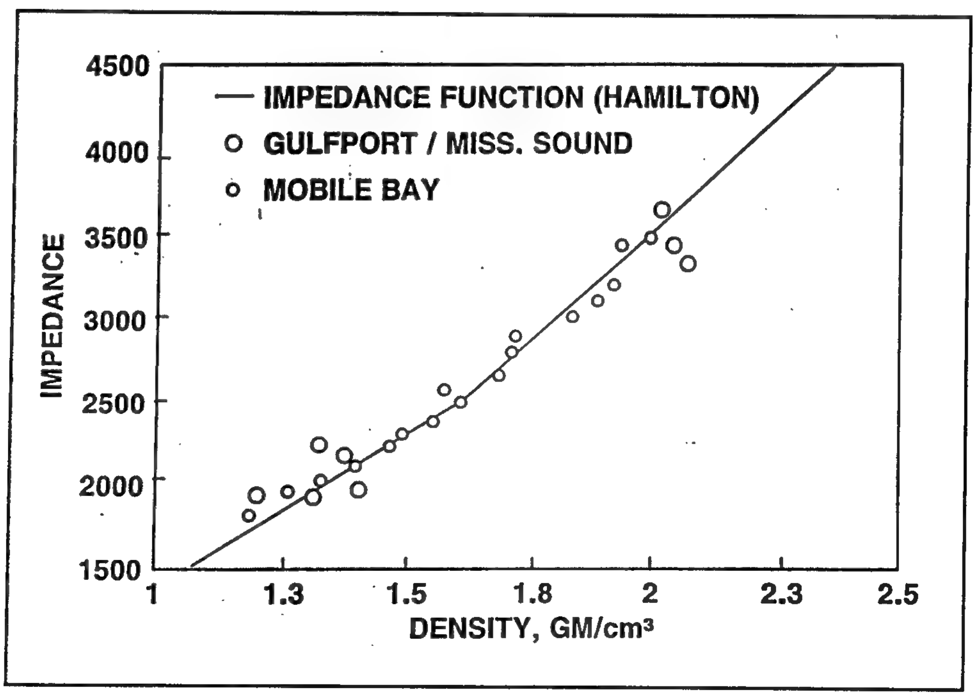


Figure 15. Density versus impedance: Gulfport/Mississippi Sound (McGee)

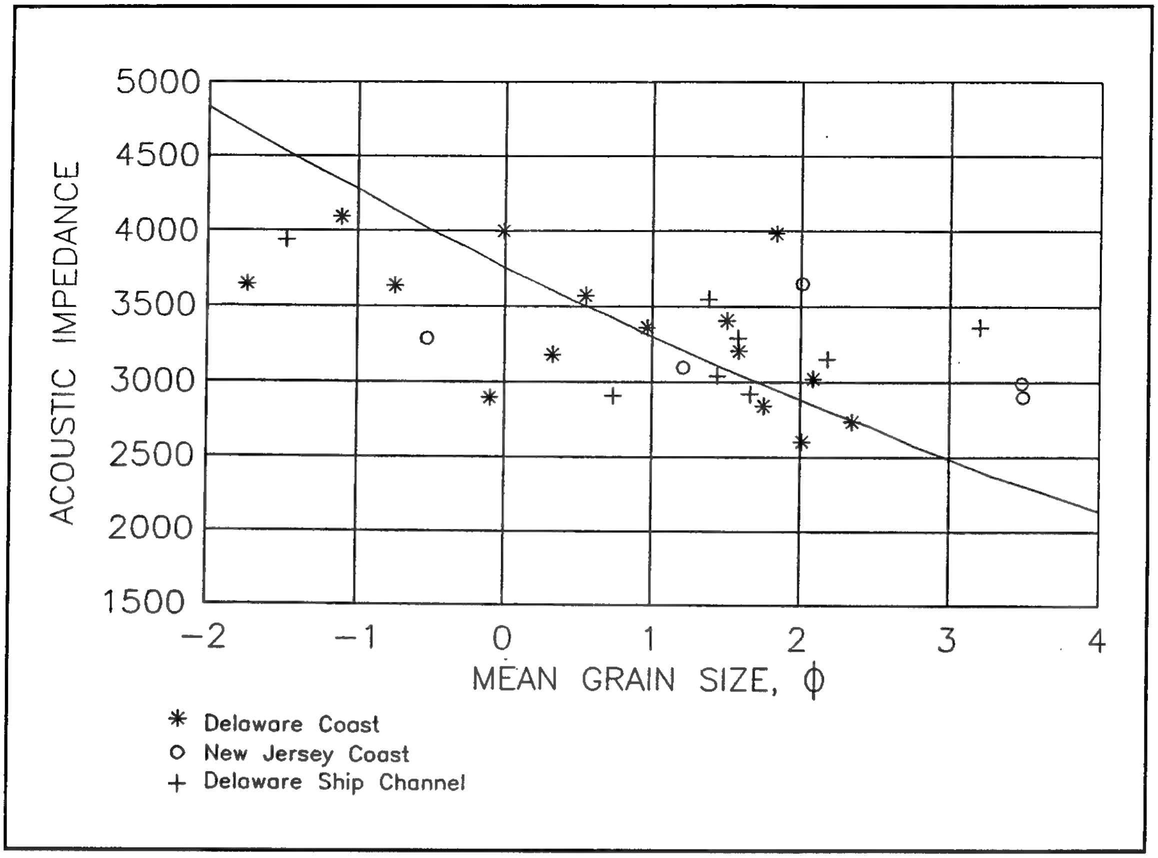


Figure 16. Mean grain size versus impedance: Delaware coast, New Jersey coast, Delaware Main Channel

measured and estimated core properties along with the acoustic and associated sediment descriptions. The acoustic values presented in Table 4 are arithmetic means of the acoustic computations for all soundings collected in the vicinity of the cores. Only sites known to consist of naturally occurring sediments are used for the calibration verification. Environments containing overconsolidated sediments, contaminated sediments, and in particular sediments containing organics have not been modelled with the AI method and are not used in the calibration procedure. The presence of organics was a major consideration during processing and analysis of these data. A discussion of organics is presented in the "Limitations" section.

Absorption model

One of the primary energy losses encountered during acoustic wave propagation through differing media is that due to absorption. This loss involves a process of conversion of acoustic energy into heat and thereby represents a true loss of acoustic energy to the medium in which propagation is taking place. Energy loss due to absorption has been researched extensively for marine sediments through which reasonable approximations of loss are provided. Hamilton (1972a) presents convincing experimental evidence to

Table 4
Acoustic Versus Sediment Properties

Core Data (DRV only)				Acoustic Measurements					
ID	#	Type[1]	ϕ_{mm}	Number of Files	Z 10^2 g/cm^{2}sec	R	BL, db[2]	ϕ_{mc}	ρ g/cm^3
27	1	SP	1.72	36	2703	0.288	10.8	1.63	1.89
26	1	SP	2.10	36	2972	0.331	9.6	0.98	2.01
25	1	SP	0.72	18	2594	0.269	11.4	1.32	1.94
24	1	SP	1.42	6	2768	0.299	10.5	0.92	2.00
23	1	SP	1.57	18	3139	0.355	9.0	0.66	2.06
22	1	SP	-2.32	36	3365	0.385	8.3	0.32	2.15
21	1	SP	-1.57	36	3588	0.412	7.7	-1.37	2.37
20	1	SP	1.40	34	3264	0.372	8.6	-0.27	2.29
19	1	SM-SC	3.21	36	3318	0.379	8.43	0.68	2.09
17	1	SP	-2.15	40	3310	0.378	8.44	0.40	2.11
15	1	SP	0.81	24	3182	0.361	8.86	0.40	2.13
3	1	GP	-2.44	28	2939	0.326	9.75	0.92	2.06

Note: Files consist of 40 consecutive soundings.
ϕ_{mm} = laboratory measured mean grain size.
Z and R computed from mean BL (shown in table) from all files in subset.
ϕ_{mc} and ρ shown are arithmetic means of individually computed ϕ and ρ of each data file in subset.
ϕ_{mc} = acoustically derived mean grain size.
[1] Unified Soil Classification. Refer also to core logs in Appendix A.
[2] $BL = 20 \log_{10} (R)$

absorption's relationship to the first power of frequency and presents the following important observations:

a. Absorption is dependent on the first power of frequency.

b. Velocity dispersion is not important.

c. Intergrain friction appears to be, by far, the dominant cause of wave-energy dampening in marine sediments.

Specifically, absorption varies as a function of frequency according to the empirical equation

$$\alpha = kf^n \tag{7}$$

where

α = absorption, db/m

k = attenuation coefficient, db/m/kHz

f = frequency, kHz

n = exponent of frequency

The constant n has been experimentally determined to be essentially unity for the frequencies of interest leaving k in Equation 7 as the only variable. This constant varies with sediment type and is related to porosity and mean grain size as shown in Figure 17. A modification of this model as described by Caulfield and Yim (1983) and Caulfield, Caulfield, and Yim (1985) is used in the AI method to estimate the engineering properties of marine sediments. A reasonable measure of absorption, in keeping with Equation 7, is provided assuming an exponential correction as a function of frequency by

$$\alpha = 10 \log_{10} e^{\frac{\rho(2\pi f)}{kc} \times X} \tag{8}$$

where

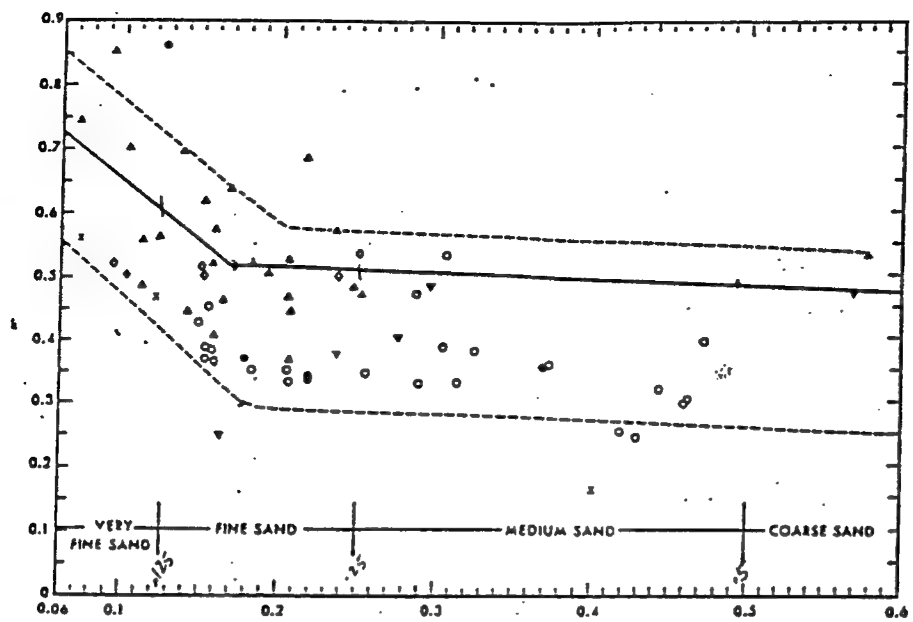
ρ = density of layer, gm/cc

k = attenuation coefficient (similar to Hamilton's)

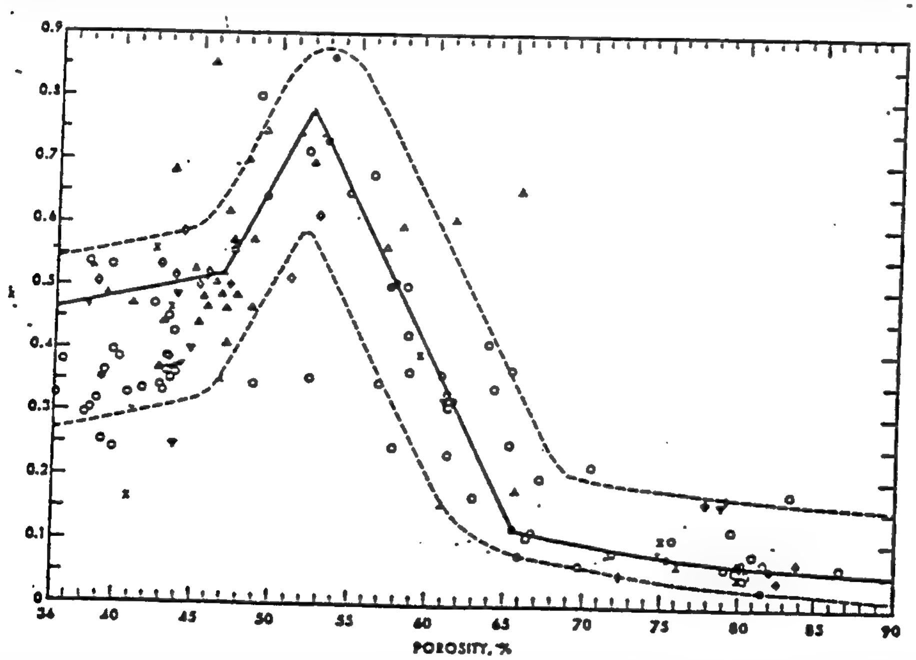
c = sound velocity of layer, m/sec

X = precision absorption correction factor

The coefficient k is either experimentally derived or estimated from Hamilton's regression equation (refer to Figure 17), and the correction factor X is included to compensate for localized variations in the absorption properties of sediments in a given geologic setting. This value, termed the "absorption factor," normally remains unity and is altered only when detailed core data are available, providing regional absorption data. The value is increased or decreased so that the deeper impedance estimates match the deeper core properties.



Mean grain size mm versus k (in $\alpha = kf^1$). Data, symbols, and remarks: same as in caption for Figure 3. Plot of mean grain size in mm emphasizes relationships in sands (see text). Regression equations for solid lines: Coarse, medium, and fine sand, in part (0.6 to 0.167 mm): $k = 0.5374 - 0.1113\ (M_z)$. Fine sand (in part), and very fine sand (0.167 to 0.063 mm): $k = 0.8439 - 1.9431\ (M_z)$.



Porosity n, percent, versus k (in $\alpha = kf^1$). Data, symbols, and remarks same as in caption for Figure 3. Regression equations for solid lines: Coarse, medium, and fine sand (36 to 46.7 percent): $k = 0.2747 + 0.00527\ (n)$. Very fine sand and lower-porosity mixed sizes (46.7 to 52 percent): $k = 0.04903\ (n) - 1.7688$. Mixed sizes (52 to 65 percent): $k = 3.3232 - 0.0489\ (n)$. Silt-clays (65 to 90 percent): $k = 0.7602 - 0.01487\ (n) + 0.000078\ (n)^2$.

Figure 17. Attenuation versus mean grain size and porosity (from Hamilton 1972a)

For the Delaware River Main Channel project the absorption factor *X* remained unchanged (X=12) from the Delaware coast AI study. This is based on the similarities between the Delaware Bay and Delaware coast physical environments; that is, in the vicinity of Delaware Bay, Pleistocene sediments form the substrate upon which the sediments of the Holocene marine transgression have been deposited (Weil 1977), which is basically the same transgressive sequence as the coast. Direct physical verification was not possible due to the lack of precise core positioning relative to the surveyed positions. In many instances, cores were more than 400 ft off the survey line. Absorption verification is provided via the acoustic core plots provided with the sediment profiles (Chapter 6) and is shown to correlate adequately with existing sample data. Individual acoustic core plots are presented in Appendix B.

Polarity of reflection coefficient

The nature of the impedance change (higher or lower) at a sediment horizon will produce either a positive or negative reflection coefficient. A negative reflection coefficient results from the phase change of the reflected signal occurring when the wave reflects off a softer layer. This phenomenon is described mathematically by rearranging Equation 2 to solve for *R* resulting in

$$R = \frac{Z_2 - Z_1}{Z_1 + Z_2} \tag{9}$$

It is readily apparent that whenever the impedance of the upper layer, Z_1, is greater than Z_2, R becomes a negative number.

Techniques have been developed to assess the reflection sign, each dependent upon the type of acoustic signal used to insonify the sediments. For wide-band frequency-modulated pulses, such as "Chirp" systems, the polarity of R is assessed using match-filter correlation techniques[1] to correlate the source wavelet with the reflected wave. Since no wide-band sonars were used for this study, a new approach was devised to exploit the pulse characteristics of band-limited acoustic pulses that relied heavily on statistical analysis rather than the aforementioned deterministic approach.

By shaping the transmit pulse into a Gaussian distribution, a peak amplitude can be detected as shown by Figure 18. After the peak amplitude of the first bottom signal is detected, a determination is then made of its polarity. Except for the case of organics, the surface material reflectivity is

[1] Correlation technique is described in Caulfield (1991a) and McGee (1995).

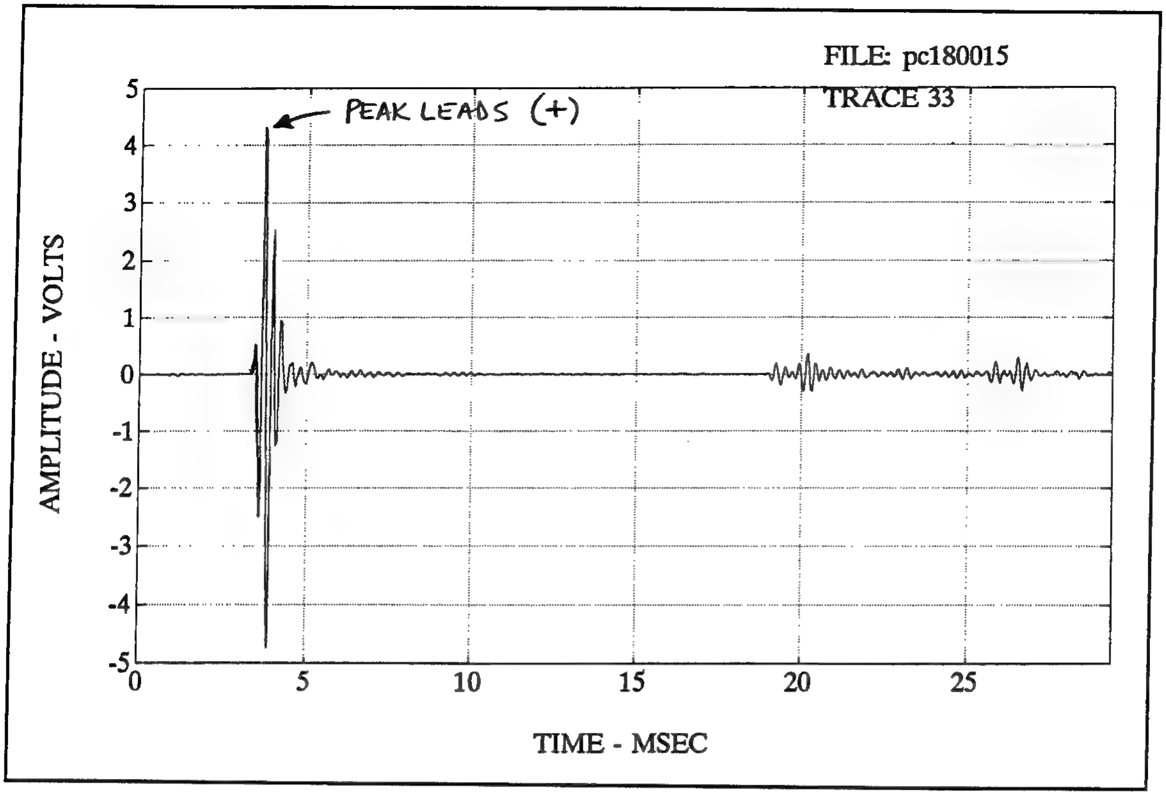


Figure 18. Shaped transmit pulse for Delaware Main Channel survey

always assumed positive since sediment structures usually have a higher impedance than seawater. Having determined this, the entire signal is scanned in the energy domain, on data above the minimum S/N ratio, and the peak at each reflecting horizon is located. Once the peak is found, data are then returned to the time domain to determine if the peak signal is positive or negative. The method uses integration constants to handle noise; however, in the presence of noise, the technique is not guaranteed to produce perfect results. It has been found, though, that by averaging results over many sequential traces, fairly reasonable results can be obtained, again showing the importance of high S/N data. This technique was used in the analysis procedure for the Delaware Main Channel study.

Limitations

As with any remote sensing technique, limitations exist. The limitations must be understood to use the method appropriately. Probably the most common fault encountered in geophysical studies is the improper application of a given technique for a given study objective. The following limitations exist for the present AI technique.

a. *Nonstandard marine sediments*. The AI model used to predict sediment density is based on natural marine sediments. Acoustically derived densities above 2.4 g/cc are <u>extrapolations</u> from empirical data derived

from mainly marine sediment environments. Without core confirmation, wet density estimates based on acoustic impedance values above 4,500 10^2 g/cm^2 sec are unverified. Sediment impedances greater than 4,500 10^2 g/cm^2 sec have been measured by Caulfield (1992) in sediments described as compacted sands, carbonate sands or coral, and very coarse sands and fine gravels. During AI surveys along the southern Atlantic coast in Charleston Harbor, South Carolina, and the Savannah Ship Channel, Georgia, a calcareous silty fine to medium sand, referred to locally as "Cooper Marl," exhibited uncharacteristically high impedance values. Whereas these sediment types are not associated with the Delaware River region, they are presented to show that certain sediment structures, herein classified as nonstandard sediments, do possess high acoustic impedance responses. Also, rock typically has impedance values greater than 4,500 10^2 g/cm^2 sec. Unfortunately, sufficient physical sediment data were not available during analysis to develop all site-specific geoacoustic parameters to comprehensively model all sediment environments of the Delaware River Main Channel. The core information available during project planning did not reveal every sediment condition encountered. No further physical exploration has been conducted.

b. Organic sediments. Applying algorithms for natural marine sediments to gassy sediments can lead to overestimation of impedance values. Organic layers may contain entrained gas bubbles. Because this gas, or air, has a markedly different density and compressibility than seawater, a high percentage of the incident sound wave will be reflected, resulting in limited acoustic penetration. A portion of this energy may also be scattered in all directions, resulting in a lack of coherency between soundings. Another characteristic of organic sediments at or near the water/sediment interface is the phase change that occurs during reflection. The bottom surface reflectivity of organic sediments will have a negative polarity response due to reflections from a water over gas- or air-bubble interface compared to what should be a positive reflection coefficient in a water over sediment configuration. In summary, the presence of organics in the sediments along the Delaware Ship Channel is assessed by a combination of core information and reflected signal characteristics, i.e., ping-ping coherency, phase reversal, high signal attenuation, and higher than normal reflectivity. Areas of suspected organics are identified on the sediment profiles; however, no acoustic impedance analysis is performed.

c. Signal-to-noise ratio. The ability to assess any environment accurately is strictly a function of the quality of the data obtained. Low S/N data will produce poor quality results or possibly no results at all. The AI method limits its processing to data with a S/N ratio greater than 5 db. One must always be suspicious of impedance predictions in areas of poor S/N. Therefore, no analysis is performed on data of poor S/N, defined as less than 5 db. The sediment profiles are annotated to identify poor S/N data.

d. *Layer identification*. Unique sediment units can be identified only when an impedance change exists. Gradual vertical changes in soil type may not result in an impedance differential large enough to produce a reflection.

e. *Resolution*. Vertical resolution and the ultimate depth of penetration are dependent primarily on the frequency of the sound wave. Higher operating frequencies permit greater resolution of the marine sediments but shallower depths of energy penetration depending on the characteristics of the subbottom materials. Also, in high-attenuation sediments, the higher frequencies are attenuated at a higher rate than the low frequencies, resulting in degradation of resolution and errors in absorption estimates for very deep layers. For this study, pulse lengths of 0.2 and 0.5 msec were selected. Vertical resolution was limited to approximately 1 ft. Vertical sediment changes occurring more rapidly than every foot are not always detected. As stated earlier, depths were adjusted to match the high-accuracy fathometer depths, providing 5:1 improvement in the depth resolution.

f. *Beam pattern or directivity*. Experience has shown that beam pattern and transducer directivity contribute significantly to signal degradation. Sloping bottoms and rapidly dipping reflection horizons cause inconsistent reflection data through focusing and defocusing of the incident energy. Rough, irregular bottoms with numerous scatterers will specularly disperse energy away from the receiving array. Sufficient notation is provided on the sediment profiles to indicate when the acoustic analysis is possibly affected by directivity problems.

g. *Core locations*. As stated in Chapter 1, the AI survey was conducted approximately 3 years after the most recent vibracore sampling program was accomplished. Consequently, many of the cores were retrieved at offsets from the main channel center line, many of which are located along the side slopes or even far outside the channel limits. It is quite possible that sediment conditions at the cores, particularly near the surface, are different from those insonified along the channel center line. Also, since the cores were not positioned based on results of the subbottom profile data, not all unique sediment environments may be sampled. All core data used in the sediment characterization are shown on the sediment profiles and in Appendix B.

h. *Relatively shallow cores*. Cores were collected to maximum depths of 20 ft below the mudline. Since the objective of the study was to identify sediments in the uppermost 20 ft of the subsurface, the core depths would seem to be sufficient. In general, they are; however, in some areas of the study, significant subsurface anomalies and nonconformities were detected below the 20-ft depth, preventing absolute verification of the acoustically derived sediment properties at these depths.

The AI method attempts to estimate the engineering properties of bottom and subbottom marine sediments in a quantitative fashion. Whenever an assumption is made based on something other than mathematical processing, that assumption is stated. Also, whenever the data are not sufficiently high in S/N, no attempt at interpretation is made, except as verified by core data. Totally subjective interpretations are avoided.

6 Discussion of Results

Sediment Profiles

The distributions of computed sediment densities and sediment descriptions within the project area are presented in Plates 2-16 as two-dimensional profiles illustrating the primary bottom and subbottom interfaces and differing zones of sediment material. For presentation purposes, the survey area is divided into segments subdividing the winding main channel into tangential profile sections. The profiles in Plates 2-16 correspond to the segments listed in Table 1 and identified in Plate 1.

The profiles illustrate the depth to a particular interface (in feet mllw), representative sediment properties, and corresponding location along the survey line. The labelled black dots at the top of each profile denote the survey track-line and direction. Each dot also represents the beginning of every seismic data file recorded to give an indication of the data coverage along each line and assist in correlating the raw data and interpreted results. The associated label represents the data file number and correlates with the data file number on the color subbottom reflection records (Figure 8). When the data file is referenced through the remainder of this report, the first three digits will indicate the data file number and the last digit will indicate the subfile number (i.e., file 0513 is data file 51, subfile 3). Philadelphia District project station numbers are included on each sediment profile. The sediment profiles have been completely adjusted for horizontal position (effects of boat speed) and survey heading. All profiles are presented heading in a northerly direction, allowing consistency in the data interpretation. Actual boat heading is in the direction of increasing data file numbers on the profiles.

All cores used during the study are identified. Since the cores were retrieved prior to the survey and are unfortunately not always located directly along the survey lines, the actual distance each core is offset from the survey is shown alongside the core position. Also, locations where precision acoustic analysis was performed, or "acoustic cores," are presented. These sites are identified by the prefix AC followed by the line number and individual file number for that line, i.e., AC-DP50-12/1. All "Acoustic Core" density plots are presented in Appendix B in ascending order along the survey track.

Sediment Description

Brandywine Range

Survey line DP50 encompasses the Brandywine Range of the main channel, beginning at approximately station 511+696 and continuing northward to the end of the range at station 448+120. The sediment profile for line DP50 is presented as Plate 2. The sediments above elevation (el) -50 between files 0000 and 0820 are characterized as predominantly fine to medium poorly graded sands with densities ranging between 1.8 and 2.0 g/cc. The surface sediments along the southern end of this line are dominated by 2- to 3-ft sandwaves from file 0040 through 0140, then becoming 1-2 ft in height to file 0230. Surface sandwaves cause random reflection diffractions away from the receiving array, inhibiting precise acoustic reflectivity analysis. Therefore, only limited acoustic analysis was performed on sediments in these areas.

A layer of silty or clayey sands is detected at about el -50 with thicknesses ranging between 5 and 10 ft. Core DRV-26 shows a silt layer 12 ft below the bottom. AC-DP50-25/1 computed a negative impedance change that correlates precisely with the sediment thicknesses shown in the core.

Core DRV-25, near files DP500560 through DP500580 (Figure 19), revealed fine to medium poorly graded sand in the upper 16 ft, followed by a 1-ft-thick layer of gravel overlying inorganic silt from el -17.5 to the bottom of the core. The acoustic data show faint horizons at approximately these depths, indicative of only slight changes in the sediment structure. The reflectivity analysis (AC-DP50-56/4 and -57/1) shows an increasing impedance sequence, comparing nicely with the lithology presented in Core DRV-24 near file 0720 where 13 ft of fine to medium poorly graded sand overlays gravelly sand.

At file 0760 a reflecting horizon at about el -80 appears (Plate 2). This horizon continues at this depth until file 0920 where it seems to slope upward, nearing the surface at file 0950. The acoustic analysis describes a material with densities typically greater than 2.2 g/cc. No core data are available for verification.

Between file 0820 and 1030 at the end of line DP50 the acoustic data show a considerable amount of lateral sediment variability. The surface sediments range between 1.6 and 2.2 g/cc. Several 1- to 2-ft-thick pockets of clays and silts (1.4-1.6 g/cc) were detected along the channel bottom between files 0960 and 1030. Three paleochannels, each penetrating the substrate to below el -60, were detected in this area. Acoustically derived densities are in the 1.6- to 1.8-g/cc range for the sediments filling the channels. Cores DRV-23 and DRV-22 confirm this analysis, showing silts and clays near the surface.

Miah Maull Range

The Miah Maull Range was surveyed as line DP51 between stations 447+560 and 404+934. The computed sediment profile is presented in Plate 3.

Surface sediments along line DP51 consist primarily of fine to coarse sands with densities ranging between 1.8 and 2.4 g/cc. Between files 0000 and 0220 the subbottom data were highly attenuated, indicative of a basically uniform stratification. Above file 0220, a rather complex geologic environment exists. A large paleovalley begins at file 0220 continuing to about file 0520 with the base of the formation reaching depths of 35 ft, from el -45 to el -80.

The surface sediments in the southern portion of the Miah Maull Range are primarily medium to coarse sands possibly containing some gravel-size materials, the coarsest of the sediments lying between files 0120 and 0220. The surface samples from cores DRV-21 and DRV-22 describe poorly graded medium sands with scattered gravels. Densities are between 2.00 and 2.3 g/cc. A couple of small clay pockets were detected at the surface at files 0090 and 0103. There are basically no subbottom data in this region.

The surface horizon in the southern portion of the range seems to form the floor of the paleovalley beginning at file 0220 as shown by Figure 20. AC-DP51-23/1 predicts a density of 2.4 g/cc at the valley floor, the same as estimated at the surface at file 0165 (AC-DP51-16/5). The uppermost sediments (top 5 ft) consist primarily of fine to medium sands ranging in density between 1.8 and 2.2 g/cc. The valley fill sediments between files 0280 and 0360 contain isolated and discontinuous reflectors, giving the sediments a weakly layered appearance. A portion of this section is shown in Figure 21. Sediment densities in the 1.6- to 1.8-g/cc range were calculated in isolated pockets throughout.

The sediment structure north of file 0350 has a uniformly layered appearance as shown by Figure 22. Core DRV-19 describes silty and clayey sands (SM-SC) in the upper 15 ft overlaying a competent gravelly sand layer. A layer of sand/silt/clay in the 1.6- to 1.8-g/cc range was detected 5-10 ft below the channel bottom between files 0350 and 0513. AC-DP51-40/2 (refer to Figure 22) presents a typical acoustic analysis for this area. This layer seems to pinch out at about file 0513. The subsurface reflectivity between files 0490 and 0550, which is the end of the Miah Maull Range, has a highly variable characteristic indicative of heterogenous sediments, possibly indicating the continued presence of these sand/silt/clay sediments in the subsurface.

Cross Ledge Range

Survey line DP52 is the Cross Ledge Range and extends between

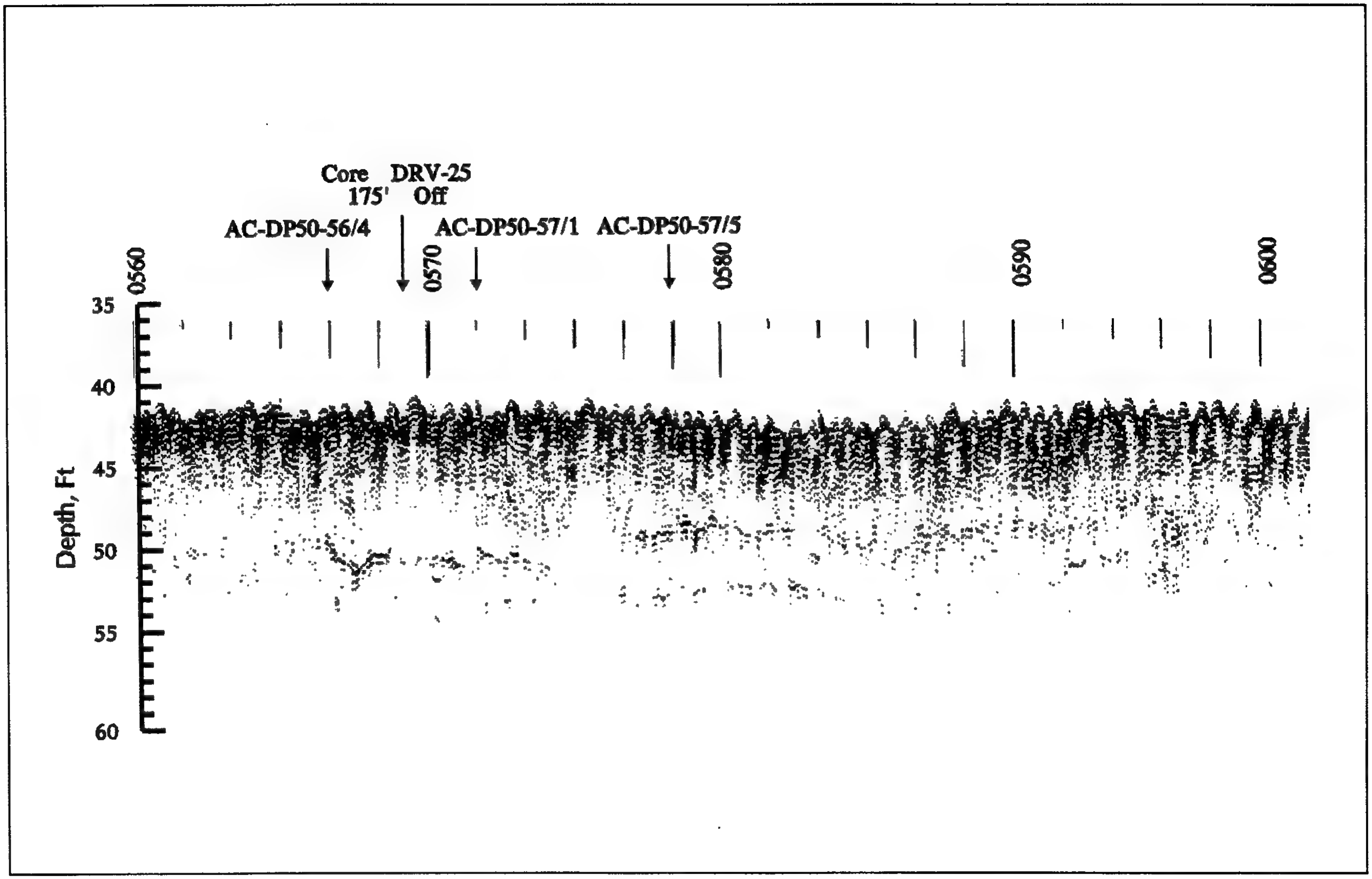


Figure 19. 3.5-kHz seismic profile data along Brandywine Range; digital files DP500560-DP500580

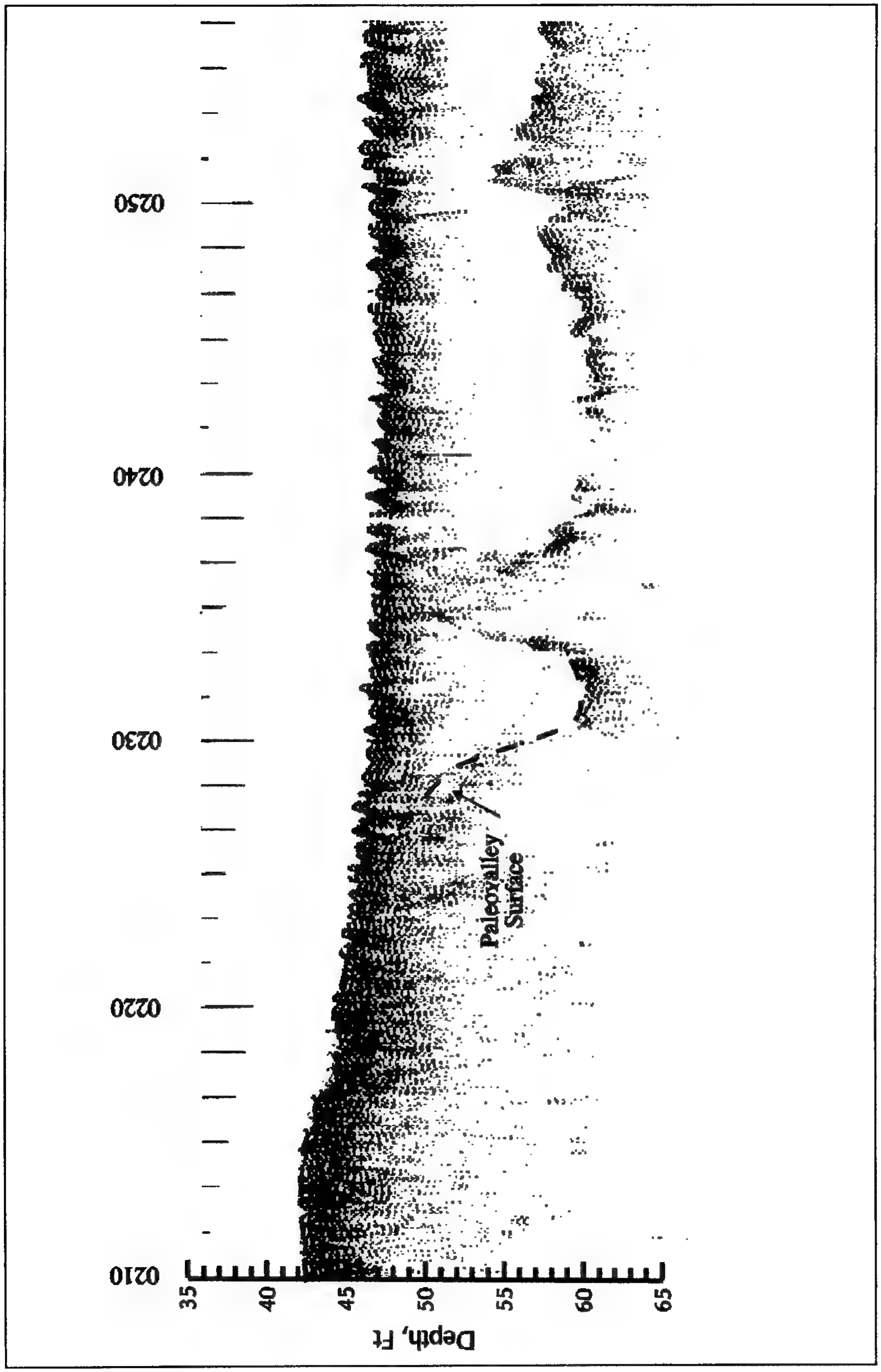


Figure 20. 3.5-kHz seismic profile data along Miah Maull Range; digital files DP510210-DP510253

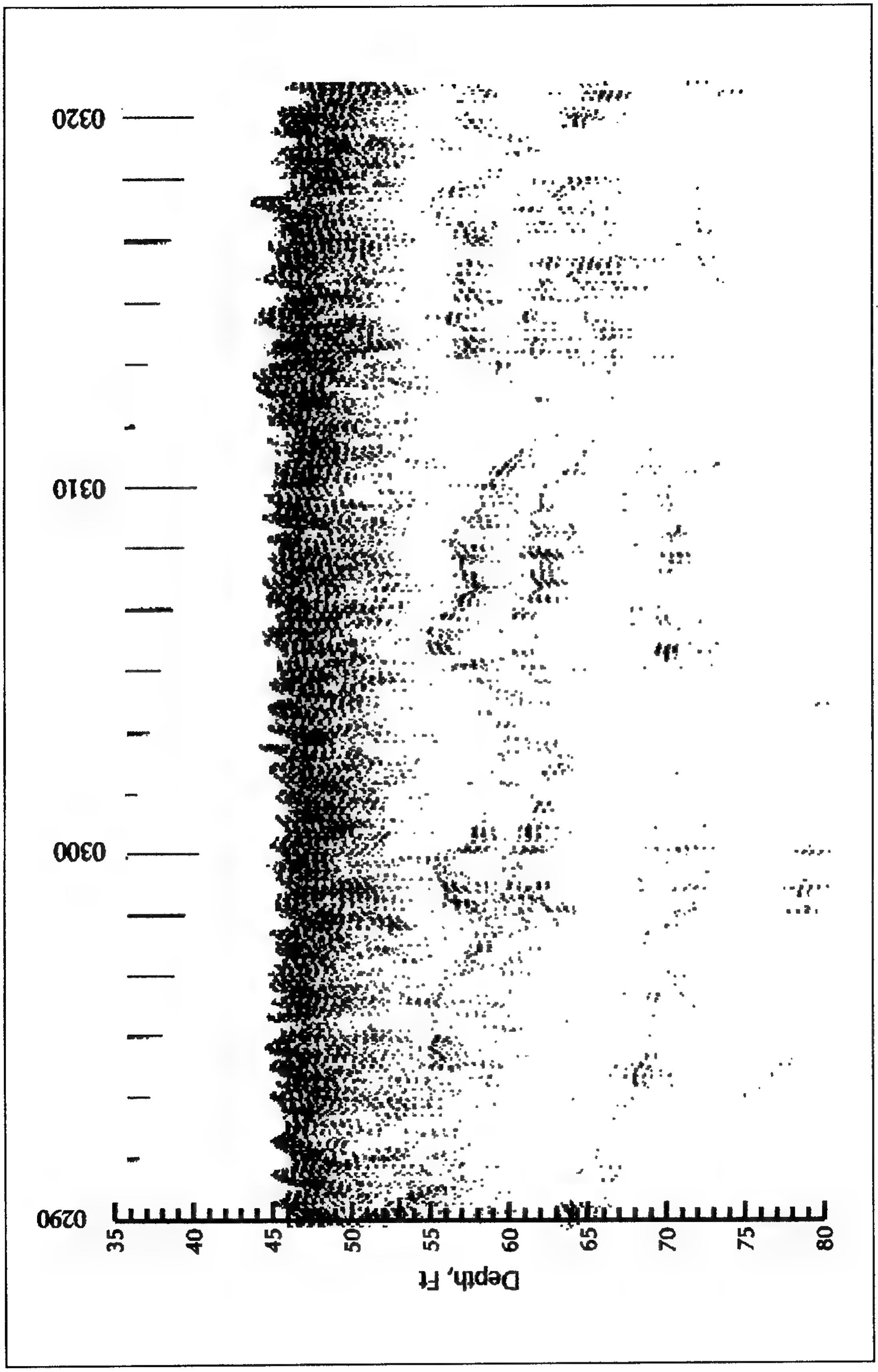


Figure 21. 3.5-kHz seismic profile data along Miah Maull Range; digital files DP510290-DP510321

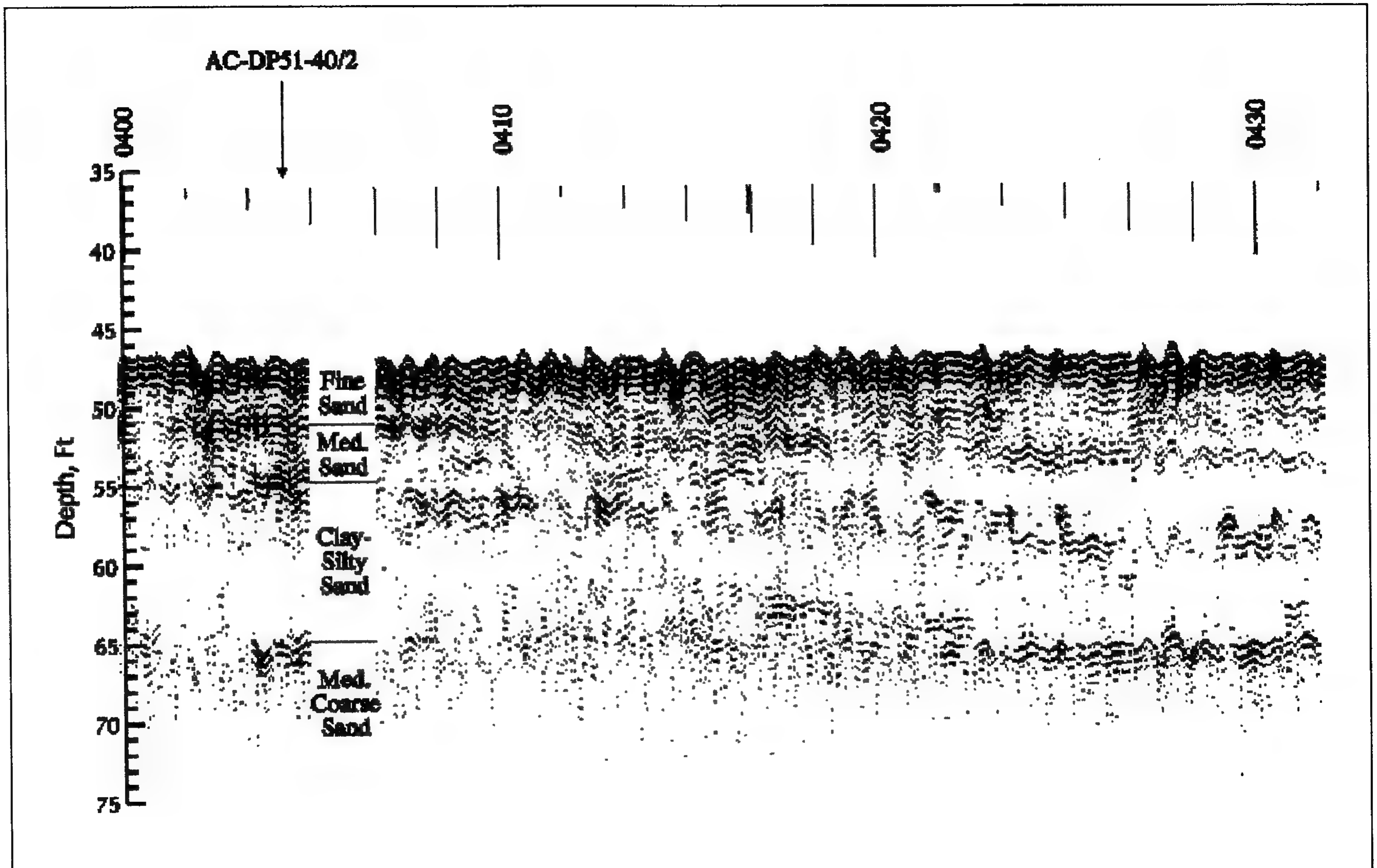


Figure 22. 3.5-kHz seismic profile data along Miah Maull Range; digital files DP510400-DP510431

stations 401+173 and 384+219. Plate 4 presents the sediment descriptions for this range. In general, the sediments through the Cross Ledge Range are consistently more competent than the previous ranges with all computed densities between 1.8 and 2.4 g/cc. Three- to four-foot sandwaves at wavelengths between 100 and 150 ft dominate the bottom topography between files 0010 and 0060. Surface densities are estimated at 1.8-2.0 g/cc, or a mostly fine to medium sand. The surface data from the end of the sandwaves to the northern end of the range at file 0215 show reaches of contrasting surface reflectivity, and therefore contrasting sediment density as shown by Plate 4.

A prominent reflector is present between el -55 and -65 for nearly the entire length of the range. Figure 23 shows the reflection data for a portion of this segment between file 0150 and 0190. This horizon is assessed in AC-DP52-12/0 with a surface density characteristic of sand to fine gravels ($\rho \approx 2.6$ g/cc) overlying a layer of medium sand before hitting the sand-fine gravel layer ($\rho \approx 2.5$ g/cc) at el -55. Moving north, the upper sediments become less competent ($\rho \approx 1.8$-2.0 g/cc), shown by a distinct contrast in acoustic signature in the subbottom data. Between files 0150 and 0180 the upper 5-10 ft may contain quantities of silts and clays, approximately 10 percent or less, and could be classified as either silty or clayey sand as shown by Core DRV-17.

Liston Range

The Liston Range encompasses the transition from the Delaware Bay to the Delaware River and is presented in Plates 5-7 as survey lines SC04A, SCO4B, and SC04C, respectively (refer also to Table 1). Line SCO4A begins at station 384+059 at file 0000 and ends at station 343+289 at file 0420 as shown by Plate 5. Line SC04B continues northward from the end point of SC04A to file 0850 at station 302+042. The northern third of the Liston Range is presented as survey line SC04C beginning at file 0850 and ending at file 1143 near station 274+790.

SCO4A. This segment (Plate 5) is characterized by frequent changes in sediment type proceeding upriver. The surface sediment densities range from very competent ($\rho > 2.2$ g/cc) to soft ($\rho < 1.6$ g/cc). A significant paleochannel depicted between files 0110 and 0230 is filled with sediments of 1.6- to 1.9-g/cc density. The upper sediment unit exhibits characteristics of lateral discontinuity and reflection amplitude variability as shown by Figure 24. Sediments are probably mixed sands, silts, and clays of varying consistency.

Between files 0250 and 0330 the surface sediments become quite competent with computed densities greater than 2.2 g/cc. The nearest core, DRV-15, which is nearly 500 ft off line, describes sediments of coarse sands and gravels, which is consistent with the acoustic results in this area. Also, numerous well-defined small pockets of silts or clays were detected along the surface, becoming more prevalent heading north. Little to no subbottom penetration was achieved.

SC04B. Beginning at file 0342 of line SC04A (Plate 5) and continuing to file 0650 of SC04B (Plate 6), a 2- to 4-ft-thick layer of heterogenous soft sediments (ρ < 1.6 g/cc) transitioning from 1.8 g/cc to 1.4 g/cc between files 0350 and 0410 overlays a seemingly more competent sediment surface with considerable lateral variability. Figure 25 is a section of the reflection profile data typical of this sediment zone. Core DRV-14 (667 ft off line) contains sand-silt-clays over firm silts and clays with interbedded organic layers in the subbottom sediments. Organic layers may contain entrained gas bubbles. Because this gas, or air, has a markedly different density and compressibility from seawater, a high percentage of the incident sound wave will be reflected, resulting in limited acoustic penetration. Since gas bubbles within sediments are strong acoustic reflectors, the use of standard algorithms for nongassy sediments can lead to overestimation of predicted impedance values. A portion of this energy may also be scattered in all directions resulting in a lack of coherency between soundings. Due to the possibility that unquantified percentages of organics may be present in these sediments, additional cores are recommended in this area for verification of the effects of organics on the acoustic technique applied.

An intriguing feature of much of the raw reflection data along lines SC04 and SC05 is an 800-Hz reverberation containing relatively high amplitude levels. An example is presented in Figure 26. This acoustic artifact is produced by the bubble pulser sound source towed approximately 50 ft behind the vessel. At this low frequency, it is believed that the bubble pulser signal is in resonance with gas bubbles entrained in organic sediments, resulting in reflection detections with the pinger receiving array located near the bow of the vessel. These are not pinger reflections; however, they are believed to be good indications of the presence of organics in the sediments since this cross-talk was not present in areas known to be free of organics. Beginning at line SC06, the bubble pulser was eliminated as a seismic source.

At file 0651 the reflection characteristics change significantly. The surface between files 0651 and 0720 consists of 3- to 4-ft sandwaves interpreted to be fine to medium sands. A major reflecting horizon was detected at about el -59 as shown in Figure 27. The high intensity of the reflection data indicates a significant and distinct contrast in sediment structure above and below this interface. Acoustically derived density estimates showed densities below this interface greater than 2.4 g/cc. An accurate acoustic assessment was difficult to perform due to the surface sandwaves, probably skewing the results low. It is therefore possible that this interface might actually be a stiff, dense clay, or as discussed previously, an organic layer. There is no core evidence suggesting this to be rock. Core information should be obtained for verification. This surface gradually slopes upward, nearing the channel bottom at file 0720.

SC04C. The data between file 0720 of line SC04B (Plate 6) and file 1060 of line SC04C (Plate 7) are basically the same throughout. A thin layer of clay/silt material (1.4-1.6 g/cc) overlays a highly reflective sediment unit through which there is no acoustic penetration. The acoustic response

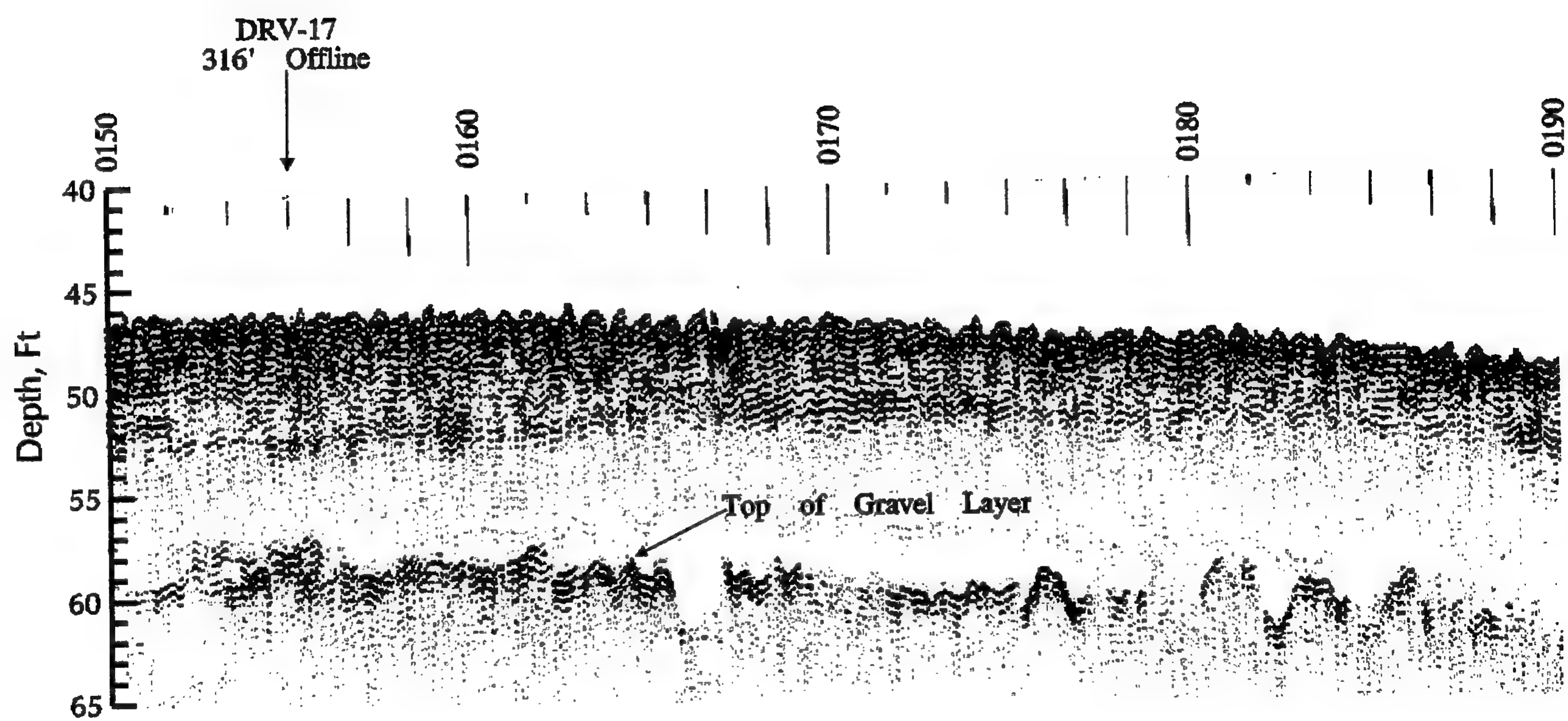


Figure 23. 3.5-kHz seismic profile data along Cross Ledge Range; digital files DP520150-DP520185

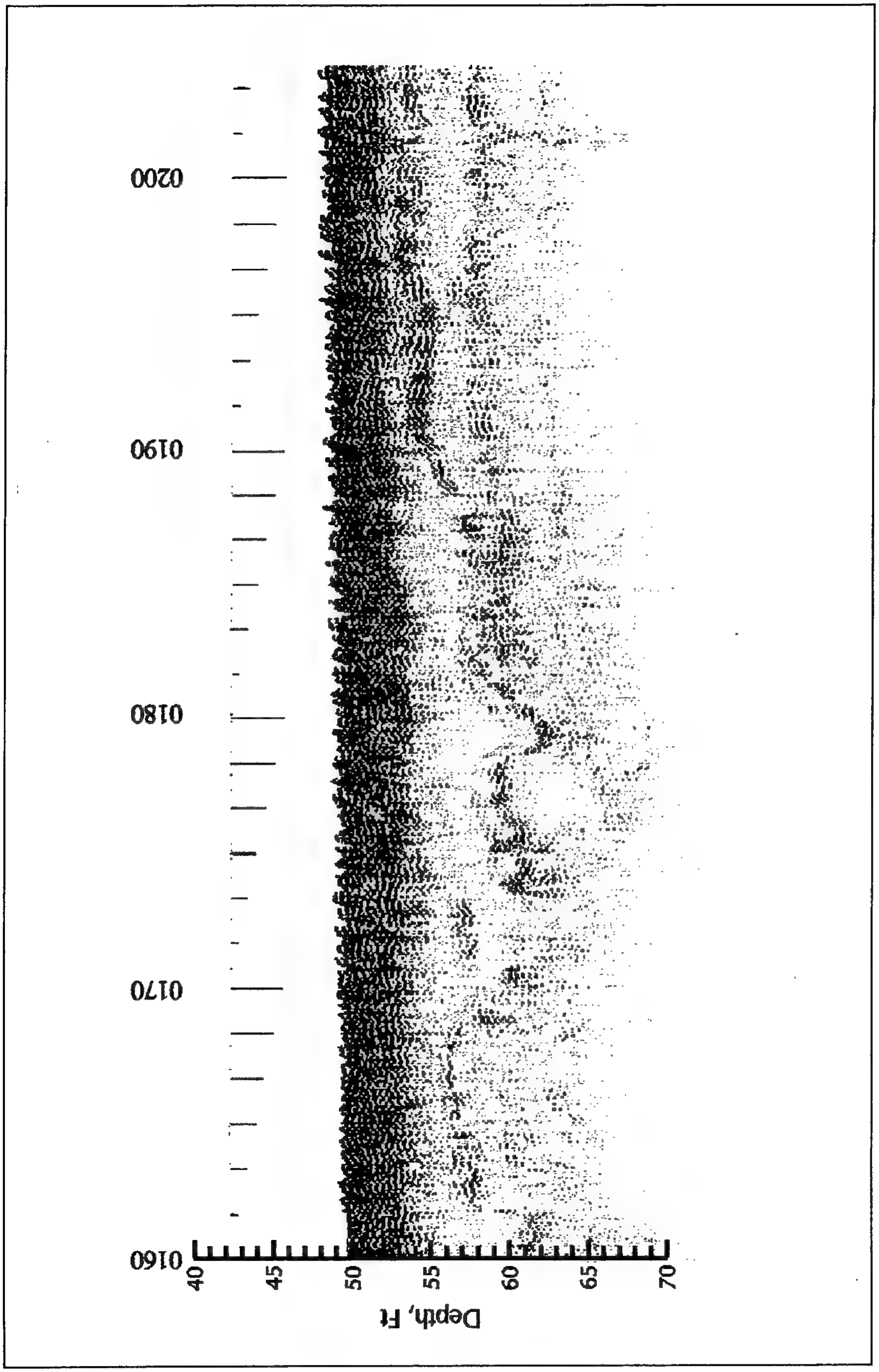


Figure 24. 3.5-kHz seismic profile data along Liston Range; digital files SC040160-SC040201

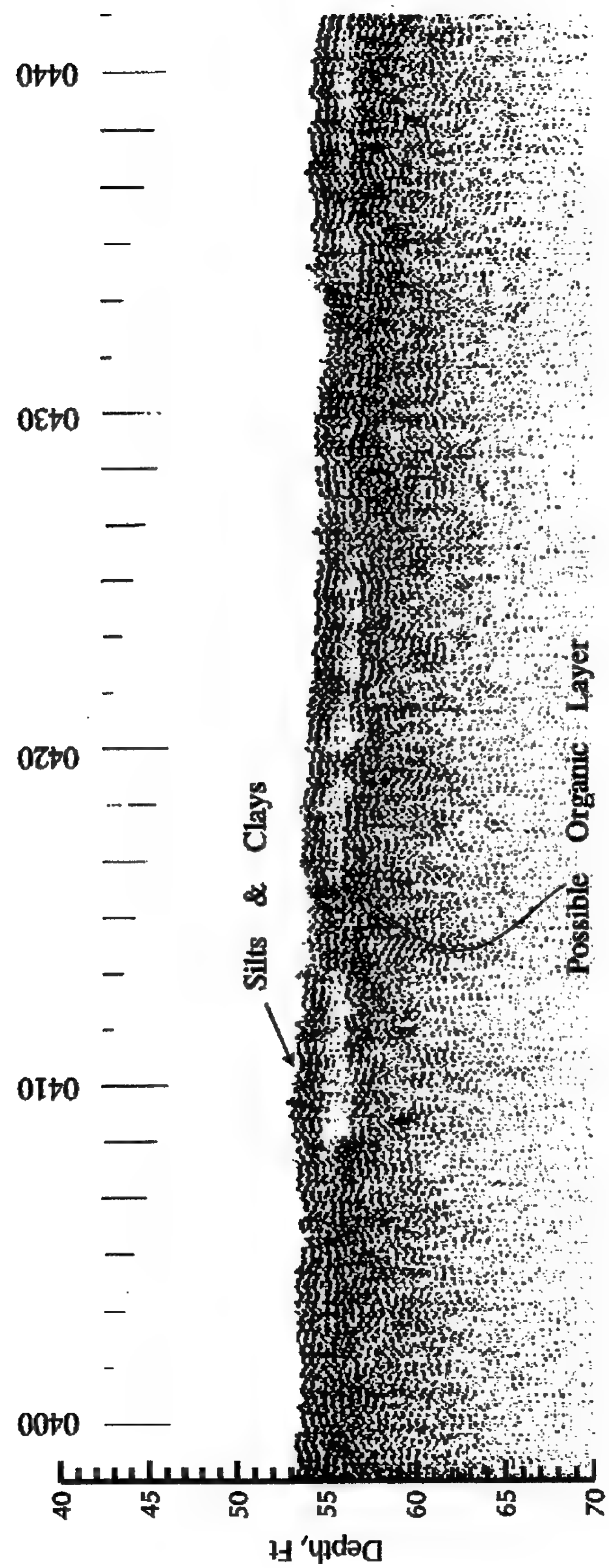


Figure 25. 3.5-kHz seismic profile data along Liston Range; digital files SC040410-SC040441

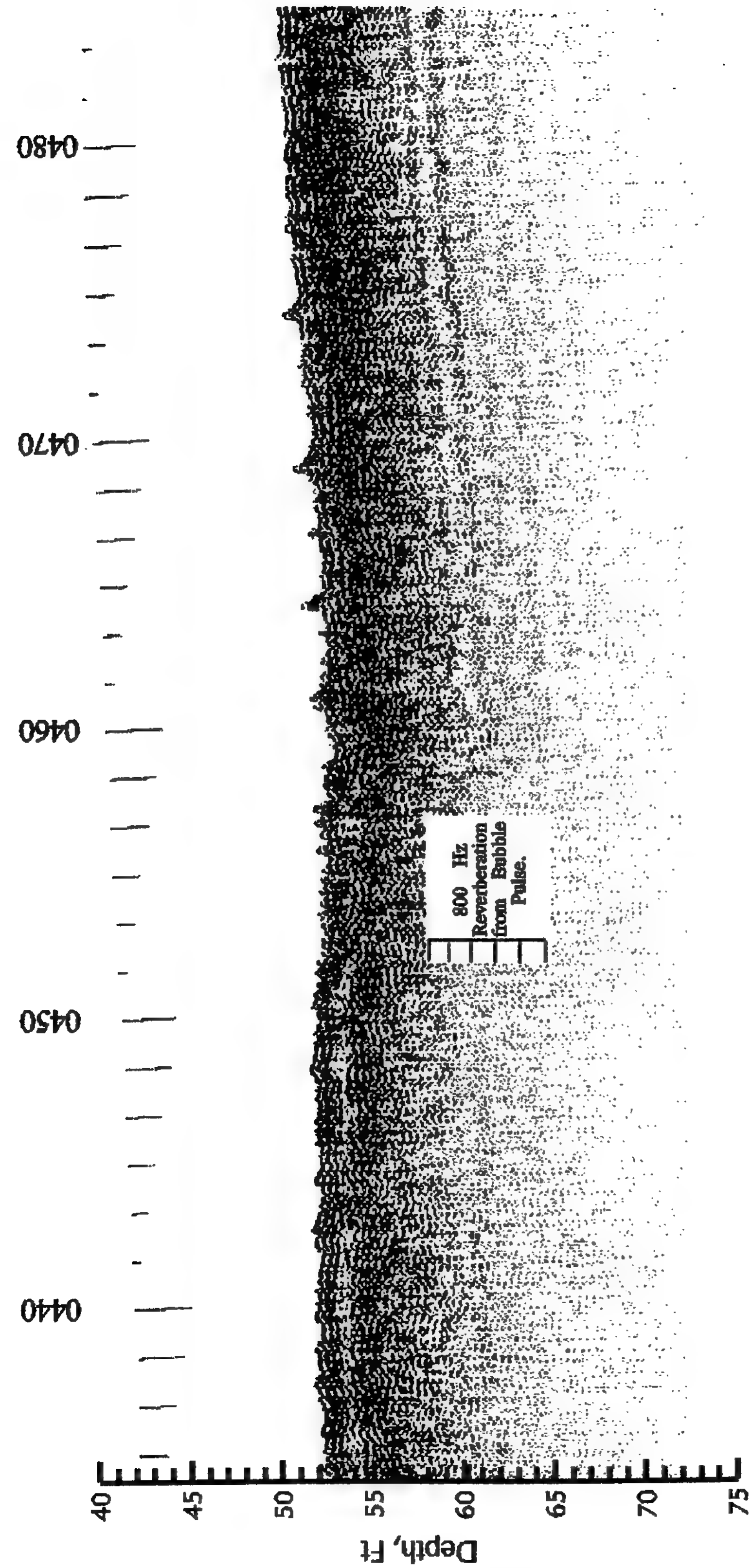


Figure 26. 3.5-kHz seismic profile data along Liston Range; digital files SC040434-SC040465

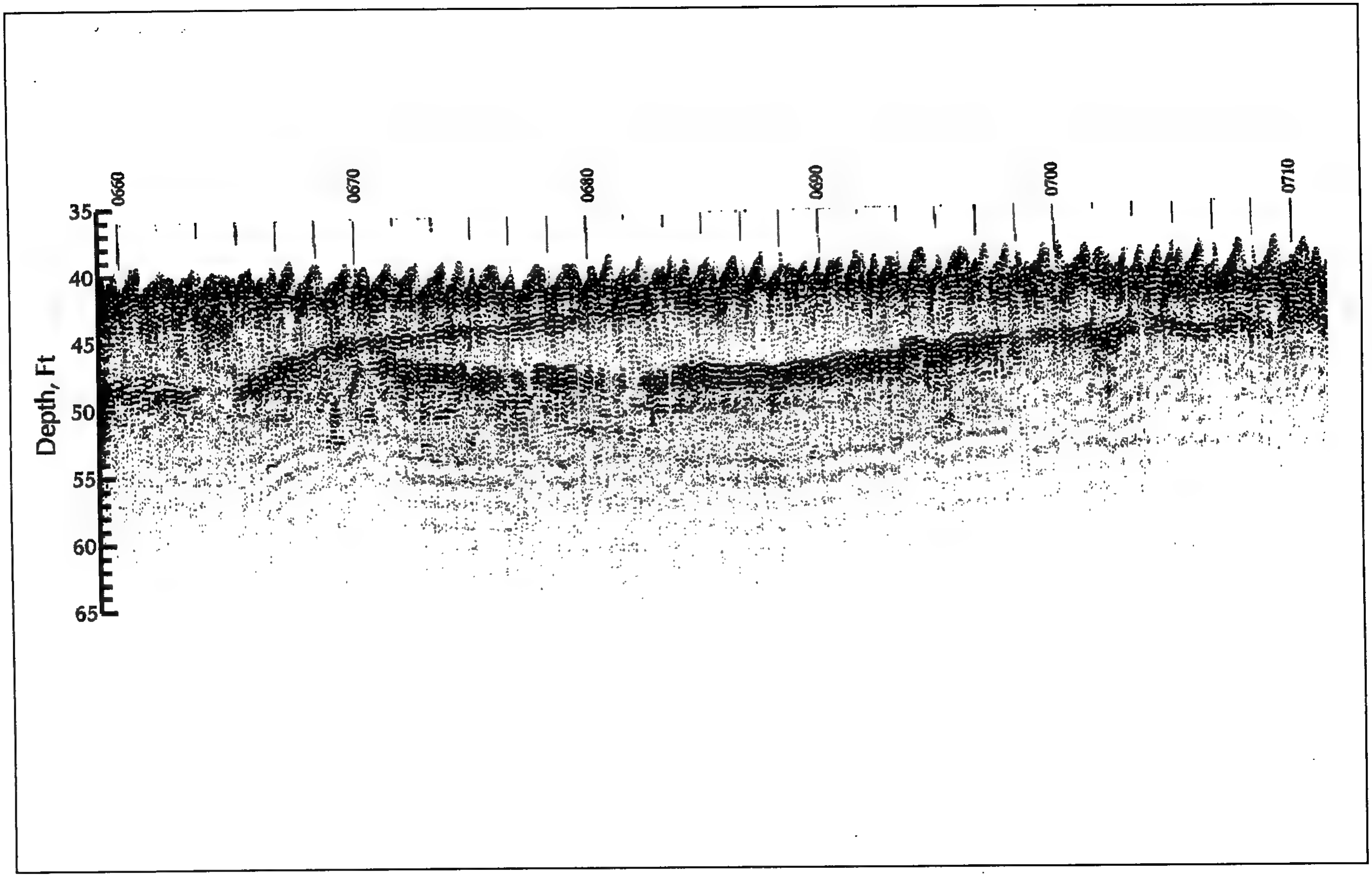


Figure 27. 3.5-kHz seismic profile data along Liston Range; digital files SC040670-SC040701

characteristics are very similar to that described between files 0350 and 0650 of line SC04B (Plate 6). Acoustically derived density estimates are all above 2.2 g/cc, reaching as high as an unrealistic 2.8 g/cc above file 1000. The cores throughout reach SC04 (DRV-14 in Plate 6 and DRV-13 and DRV-12 in Plate 8) all consist of sediments described as predominantly clays and silts with some sand faces. Organics are present in all cores. Due to the high reflectivity potential of gassy sediments (organics), impedance calculations in this area are suspected to be high relative to the actual sediments encountered. Therefore, acoustically derived density estimates for sediments below the soft surface layer are most likely not applicable and are subsequently not presented. Additional cores are needed for identification of these sediments.

One- to two-foot surface sandwaves are present in the northernmost reach of the Liston Range between files 1060 and 1110. Then beginning at file 1110, a 3- to 5-ft thick layer of silts and clays overlays a competent subbottom horizon through which no acoustic penetration was achieved. This layer is presented as a material with a density of 2.2-2.4 g/cc; however, it does exhibit considerable lateral reflection amplitude variability. The reflection data between files 1110 and 1130 resemble the data between files 0420 and 0650 of line SC04B (Plate 6) described as organic. Since no core evidence exists to indicate otherwise, there is no reason to believe that sediments here are not also organic.

Baker Range and Reedy Island Range

Acoustic files SC050000 - 0120 include the Baker Range followed immediately by the Reedy Island Range between files 0120 and 0450. The sediment profile for these ranges is presented in Plate 8.

The same sediment environment described for the northern end of the Liston Range continues northward to about file SC050090 of the Baker Range. An upper layer of predominantly fine material (ρ < 1.6 g/cc) is shown in Figure 28 overlaying an acoustically impenetrable layer. The upper layer becomes more competent upriver until it pinches out completely at file 0093, likely due to increasing percentages of sands in the sediments. Core DRV-13, nearly 250 ft off line, describes a silt-clay sediment overlaying sands with gravels. This correlates precisely with the acoustic estimates from AC-SC05-3/3 and AC-SC05-4/1 where sediment densities of 1.5-1.6 g/cc and 1.9-2.2 g/cc were predicted for the upper and lower sediment units, respectively. Even though Core DRV-13 correlates with the acoustic data at the beginning of line SC05, there is still some concern about the possible presence of organics in the sediments.

Beginning at file 0100, surface densities based on reflectivity analysis range between 1.8 and 2.5 g/cc, indicative of predominantly sands and gravels. There is essentially no acoustic penetration into the subbottom through file 0270. At this point a weak, yet distinctive reflector is detected at

about el -60, rising to within 2 ft of channel bottom at file 0344. Analysis of the surface data reveals a highly competent overburden sediment ($\rho \approx 2.0$-2.2 g/cc). Beginning at file 0350, a 1- to 2-ft thick layer of silt-clay sediment (1.4-1.6 g/cc) overlays a highly reflective sediment unit until it surfaces at file 0500. Acoustic cores AC-SC05-37/4, -46/0, and -51/0 estimated sediment densities around 2.4 g/cc; however, this density estimate is questionable due to the potential organic matter in these sediments. Cores 463, 461, and 459 (refer to Appendix A, Table A1) present highly variable sediment conditions, ranging from organic silts and clays to coarse sands and gravels. Core DRV-12, nearly 450 ft off line, at the end of line SC05 shows organic silty clay near the surface. There is no acoustic penetration through this sediment unit.

New Castle and Bulkhead Bar Ranges

Acoustic files SC060120 through SC060520 include the New Castle and Bulkhead Bar Ranges and the beginning of the Deepwater Point Range. The sediment profile for these ranges is presented in Plate 9. The sediments between files 0120 and 0240 consist primarily of organic silts and clays as described in Core DRV-12 and cores DSP-1, DSP-2, DSP-3, and DSP-4. At file 0240 the sediment environment becomes fine to medium sand. Figure 29 shows the seismic data as it progresses out of organic sediments into primarily fine to medium sands. Core DSP-5 shows sand and gravel, correlating with acoustic cores AC-SC06-40/0, -41/2, and -42/0. The sediment structure remains similar progressing upriver with sediment densities increasing to greater than 2.2 g/cc near file 0413. Cores DFP-43 through DFP-45 and DSP-5 are representative of the sediments insonified along the Bulkhead Range and describe coarse sands and gravels with occasional cobble sizes through file 0650 (Plate 10).

Deepwater Point Range

The Deepwater Point Range, files SC060590-1015 in Plate 10, consists of primarily organic clays and silts along the survey line. The data show an acoustically impenetrable and highly reflective sediment horizon indicative of the response common to gassy, organic sediments. All cores from this area (refer to Plate 10 and Appendix B) describe organic silty clays.

Cherry Island and Bellevue Ranges

As with the Deepwater Point Range, much of the acoustic data for the Cherry Island and Bellevue Ranges is characterized by high surface reflectivity values associated with limited acoustic penetration as shown in Plate 11. However, the core data available for this region of the main channel vary from organic silts and clays (DRV-10, DSP-9, 435, and 436) to stiff clays with cobbles (431) to sandy gravels and cobbles (437, 438). Two sections are presented in this area as not organic: files 1110-1240 and 1510-1610 in

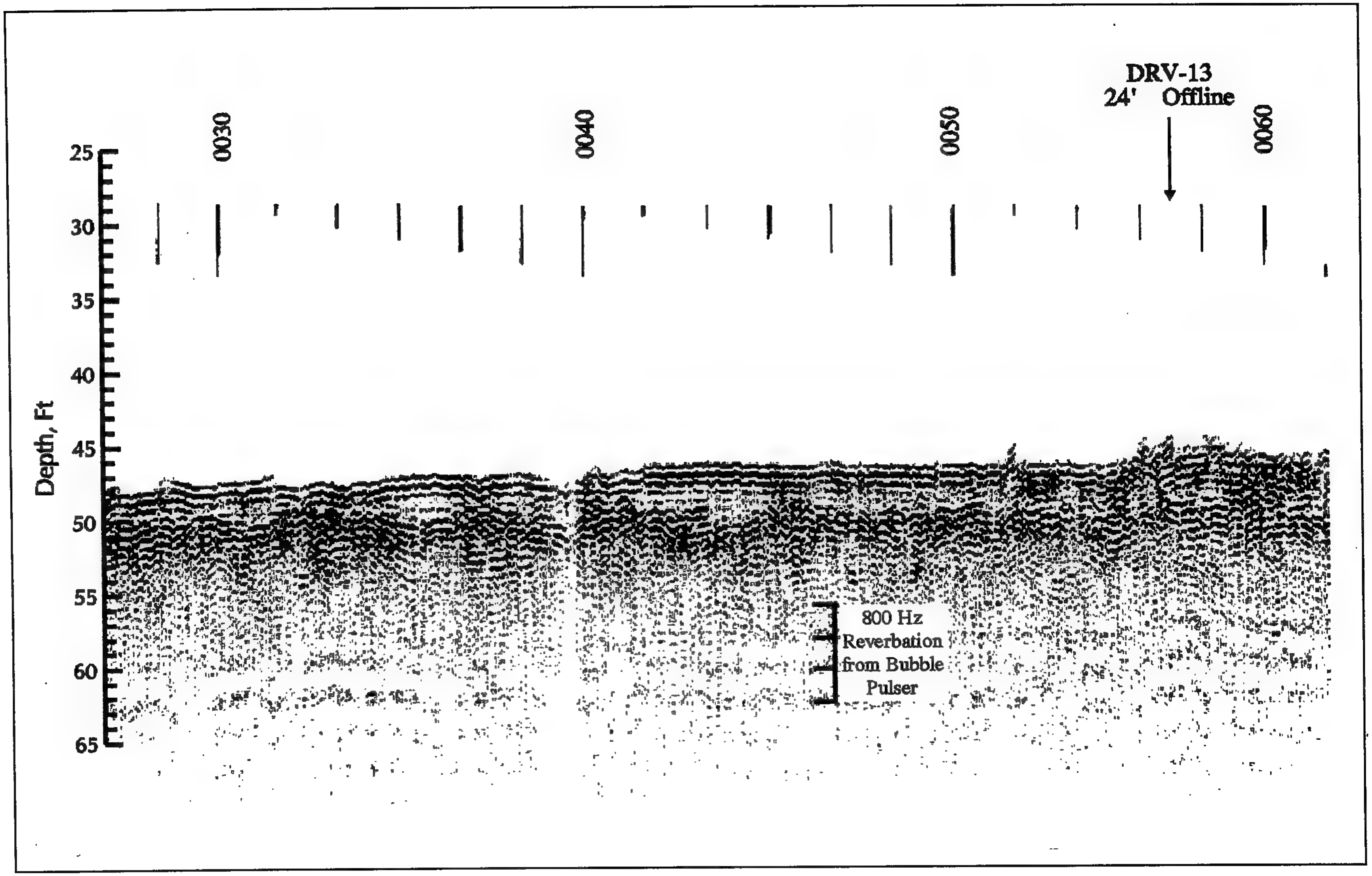


Figure 28. 3.5-kHz seismic profile data along Baker Range; digital files SC050025-SC050060

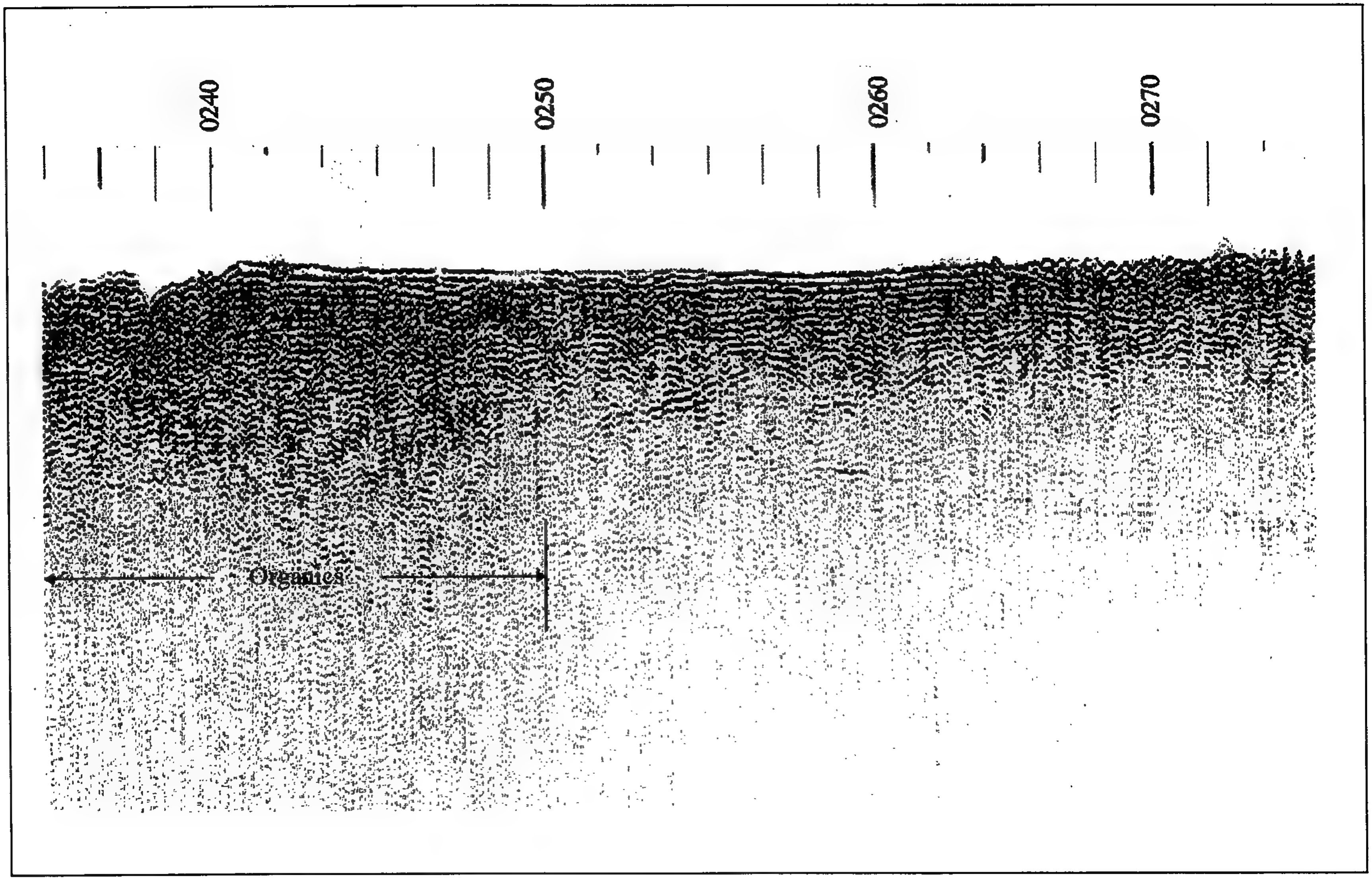


Figure 29. 3.5-kHz seismic profile data along New Castle and Bulkhead Bar Ranges; digital files SC060233-SC060264

Plate 11. The former area has high reflectivity variability in both the bottom and subbottom data with surface densities varying between 1.4 and 2.2 g/cc. The subbottom is characterized as firm silt and sand mixtures with quantities of organics. The latter section, near the end of the Bellevue Range, seems to consist of sandy gravels and cobbles with densities typically greater than 2.2 g/cc. Highly competent surfaces are shown in this area, possibly rock, but as shown by core 438, could be sandy gravel with cobbles and boulders.

Marcus Hook, Chester, and Eddystone Ranges

Plate 12 presents the sediment profiles for the Marcus Hook through Eddystone Ranges. The sediments are primarily coarse sands and gravels except for an area of organic silts (refer to core 282) between files 1780 and 1860. Several rock pinnacles and buried rock surfaces were detected as shown by Figure 30 and noted in Plate 12. Rock (weathered schist) was detected in cores DRV-7, DRV-5, and DRV-4 at approximately el -49.

A review of older epoch cores outside the main channel beginning with the Cherry Island Range and extending through Eddystone revealed that along the eastern side of the center line primarily organic sediments (silts and clays) were present and on the western side mostly sands, gravels, and rocks. This correlates with geologic conditions reported by Weil (1977) that the navigation channel parallels to the fall line with early Paleozoic metamorphic rocks on the west and unconsolidated Coastal Plain sediments on the east. Due to the highly reflective nature of all these sediment structures, it is very difficult to absolutely determine the sediment types using strictly impedance computations.

Tinicum, Billingsport, and Mifflin Ranges

The southern half of the Tinicum Range between files 2040 and 2140 has areas of 3- to 4-ft sandwaves along the channel bottom (Plate 13). A possible rock surface is detected about el -50 in this area. This possible rock surface is detected through the Mifflin Range ending at about file 2420. Acoustically derived density values are possibly low here due to directivity problems related to the sandwaves. Core DRV-3 near file 2130 contains primarily gravels. Acoustic densities exceed 2.2 g/cc.

Except for a section of organic sediments between files 2270 and 2340, the Billingsport and Mifflin Ranges consist of fine to medium sands with densities between 1.8 and 2.2 g/cc. As shown in Plate 13, areas of soft surface sediments exist, especially between files 2340 and 2410 where the acoustic data are characterized by discontinuous reflectors, indicative of a heterogeneous sediment distribution and numerous pockets of soft sediment.

Horseshoe and Fisher Point Ranges

As shown in Plate 14, a more complex geologic environment exists through the Horseshoe and Fisher Point Ranges. Two paleochannels filled with silts, clays, and fine sands overlay a coarse sand and gravel horizon detected as deep as el -80. This layer is at the channel bottom surface at files 2440 and 2480. Numerous subbottom reflectors are shown in the fill sediments of the paleochannels. These are described as discontinuous with low reflectivity characteristics indicative of only subtle changes in sediment structure. This sediment environment continues upriver in the Fisher Range to file 2580 as shown in Plate 15. A mostly silt-sand sediment environment exists through file 2650 where another highly reflective and acoustically impenetrable surface material typical of organic sediments is encountered and continued to file 2690 in Plate 16. At this point to the end of survey at the Ben Franklin Bridge the sediments are characterized as medium sands with densities between 2.0 and 2.2 g/cc. Significant sandwaves are seen along the channel bottom, limiting acoustic analysis. There is limited acoustic penetration through this reach.

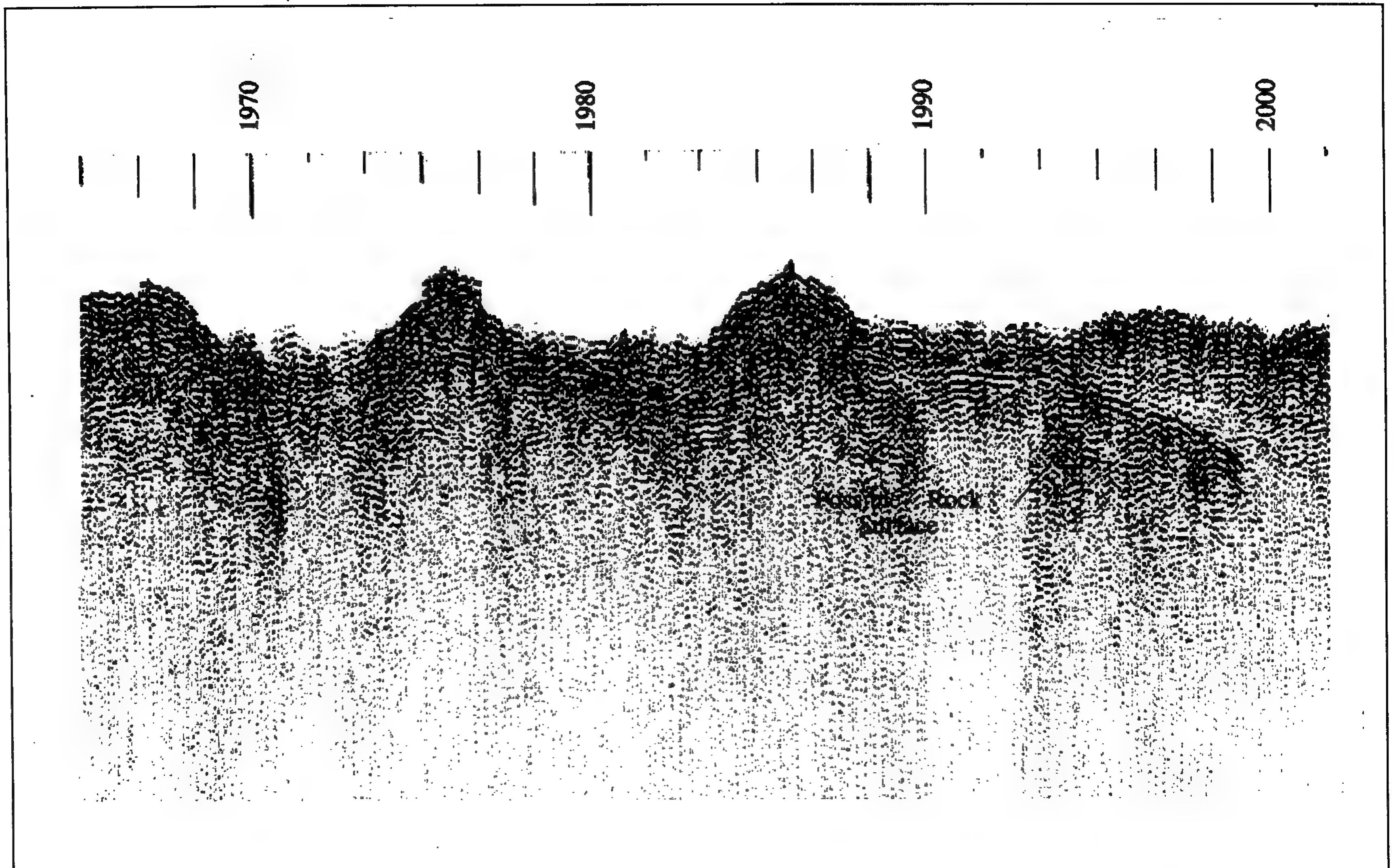


Figure 30. 3.5-kHz seismic profile data along Marcus Hook, Chester, and Eddystone Ranges; digital files SC061964-SC061995

7 Summary

Comprehensive analysis of 800- and 3500-Hz seismic reflection data in conjunction with vibracore sampling data collected along the Delaware Main Shipping Channel, Delaware, has been accomplished. The seismic data were correlated with the laboratory analysis of the sample data through acoustic impedance analysis. Results are in the form of sediment profiles (Plates 2-16) presenting the major reflection faces with descriptions of the engineering properties of the insonified sediments, i.e., wet density, mean grain size, and associated soil types, and acoustically derived density versus depth plots herein referred to as Acoustic Cores (Appendix B). The study objective to quantify the bottom and subbottom sediments in terms of density and soil type below the existing ship channel center line for the purpose of assessing their removal through dredging was met.

Geoacoustic Modelling

Geoacoustic relationships

The Delaware River Main Channel sediment characterization developed to relate density, mean grain size, and soil type is provided in Table 3 delineating the predominantly clay, silt, and sand sediment types. No laboratory measurements of density were available for any of the cores used for this study. Therefore, the geoacoustic model relating impedance to density was taken from previously established databases. It has been shown that with data of high S/N and for naturally occurring sediments, density estimates based on acoustic impedance can be estimated within ± 10 percent. Had density measurements been available, the accuracy of the results could have been improved to within about ± 5 percent. However, the ± 10 percent should be sufficient to meet the study objectives. Impedance versus grain size is modelled according to the geoacoustic relationship developed for an AI study off the Delaware Coast. This is due to the lack of comprehensive grain size analysis (i.e., no grain size measurement of fines below No. 200 seive) from the previously acquired cores used for this study.

Nonstandard marine sediments

The AI model used to predict sediment density is based on natural marine sediments. Acoustically derived densities above 2.4 g/cc are extrapolations from empirical data derived from mainly marine sediment environments. Without core confirmation, wet density estimates based on acoustic impedance values above 4,500 10^2 g/cm^2 sec are unverified. Rock typically has impedance values greater than 4,500 10^2 g/cm^2 sec. More physical sediment data are required to absolutely verify insonified areas of the main channel where materials such as rock and organic-rich silts and clays are present.

Organic sediments

Using algorithms for natural marine sediments containing gasses, such as organics, can lead to overestimation of impedance values. The presence of organics in many areas along the main channel created considerable difficulties in properly characterizing the sediments in these areas. Further verification through physical sampling would be beneficial. All areas suspected of possessing organics are identified on the sediment profiles. Most of the organic-rich sediments in the main channel have been identified through sampling as unconsolidated silts and clays.

Sediment Characterization

Brandywine through Cross Ledge Ranges

These ranges (Plates 2-4) basically encompass the Delaware Bay portion of the main channel. The sediments along these ranges consist primarily of fine to coarse sands with much of the bottom topography consisting of sandwaves. Several paleochannels and a major paleovalley were detected in the Brandywine and Miah Maull Ranges with fill sediments described as silty and clayey sands. The sediments through the Cross Ledge Range were consistently more competent with computed densities between 1.8 and 2.4 g/cc.

Liston through Deepwater Point Range

The Liston range (Plates 5-7) encompasses the transition from the Delaware Bay to the Delaware River proper. Frequent changes in sediment type are noted proceeding upriver. Many of the sediment units exhibit characteristics of lateral discontinuity and reflection amplitude variability. Sands, silts, and clays are present. In many areas little or no acoustic penetration was achieved. Most of the impenetrable areas are organic-rich silts and clays and continue through the Deepwater Point Range (refer to Plates 8-10).

Cherry Island through Eddystone Range

These ranges, presented in Plates 11 and 12, parallel much of the Fall Line of early Paleozoic metamorphic rock where it meets basically unconsolidated Coastal Plain sediments to the east. Consequently, the sediment descriptions through these ranges are highly variable from organic silts and clays to stiff clays with cobbles as well as sandy gravels, cobbles, and rocks. Several areas within these reaches are identified as possibly rock. In general, based mainly on core data, organic-rich unconsolidated sediments are located on the eastern side of the channel center line and sands, gravels, and rocks on the western side.

Tinicum through Fisher Point Range

A possible rock surface was detected at about el -50 from the Tinicum through the Mifflin Range (Plates 13 and 14) underlying primarily fine to medium sands. Numerous pockets of soft sediments (silts and clays) were detected along the channel bottom. The Horseshoe and Fisher Point Ranges present a fairly complex geologic environment with sand/silt/clay-filled paleo-channels overlying coarse sands and gravels. Except for a short segment of possible organic sediments in these ranges, the sediments through the end of survey at the Ben Franklin Bridge are characterized as mainly medium sands.

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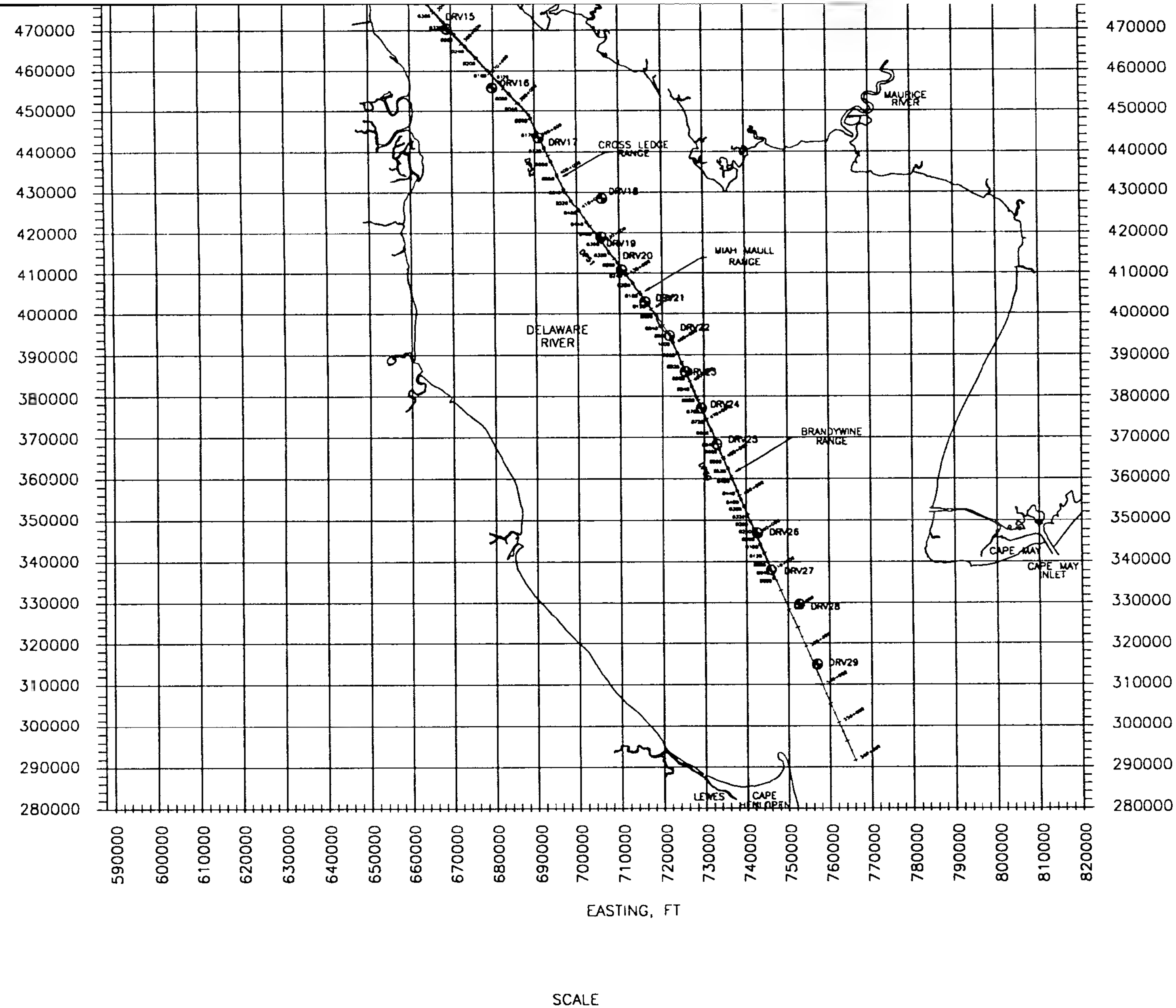


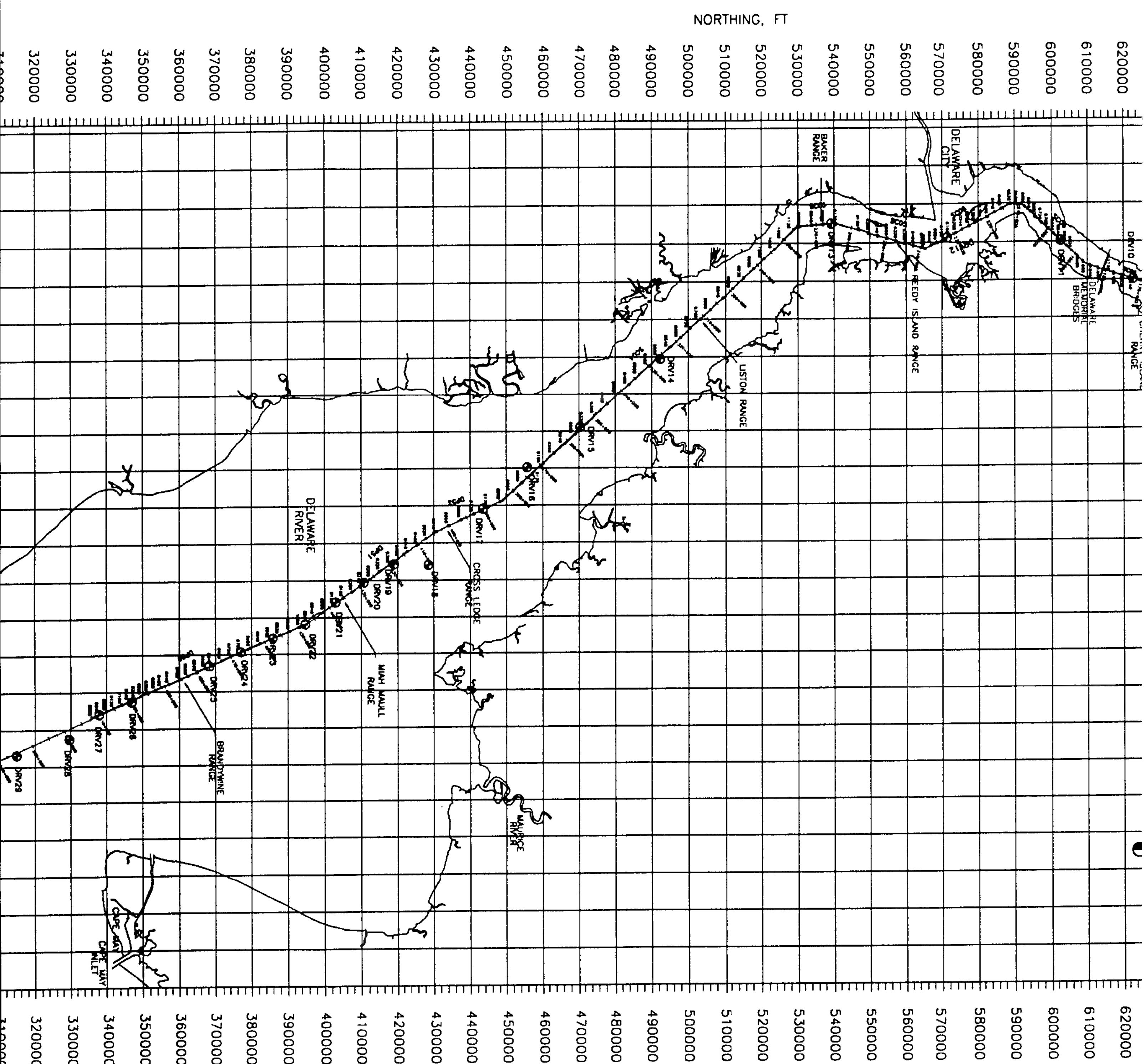
WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
1993 GEOACOUSTIC SURVEY

FILE NAME: DELSHIP.DWG

SCALE: AS NOTED | DATE: JANUARY 10, 1995 | PLATE 1

(1)



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BAKER RANGE
DELAWARE CITY
REEDY ISLAND RANGE
DELAWARE MEMORIAL BRIDGES
LISTON RANGE
DELAWARE RIVER
CROSS LEDGE RANGE
MIAH MAULL RANGE
BRANDYWINE RANGE
MAURICE RIVER
CAPE MAY
CAPE MAY INLET
DRV10
DRV11
DRV13
DRV14
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DRV29

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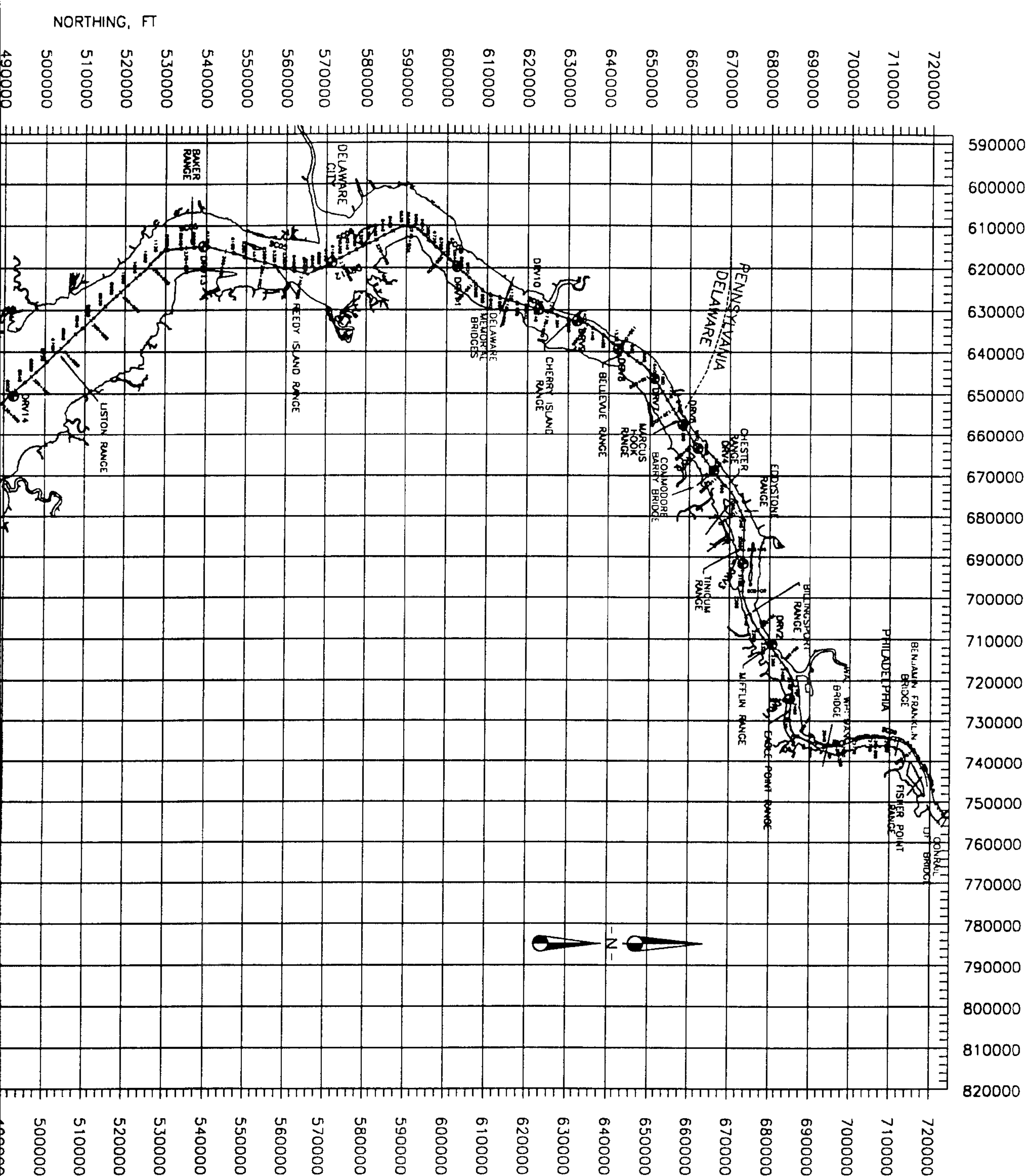

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BAKER RANGE
DELAWARE CITY
REEDY ISLAND RANGE
LISTON RANGE
DELAWARE MEMORIAL BRIDGES
CHERRY ISLAND RANGE
BELLEVUE RANGE
MARCUS HOOK RANGE
COMMODORE BARRY BRIDGE
PENNSYLVANIA
DELAWARE
CHESTER RANGE
EDDYSTONE RANGE
TINICUM RANGE
BILLINGSPORT RANGE
MIFFLIN RANGE
EAGLE POINT RANGE
PHILADELPHIA
BENJAMIN FRANKLIN BRIDGE
FISHER POINT RANGE
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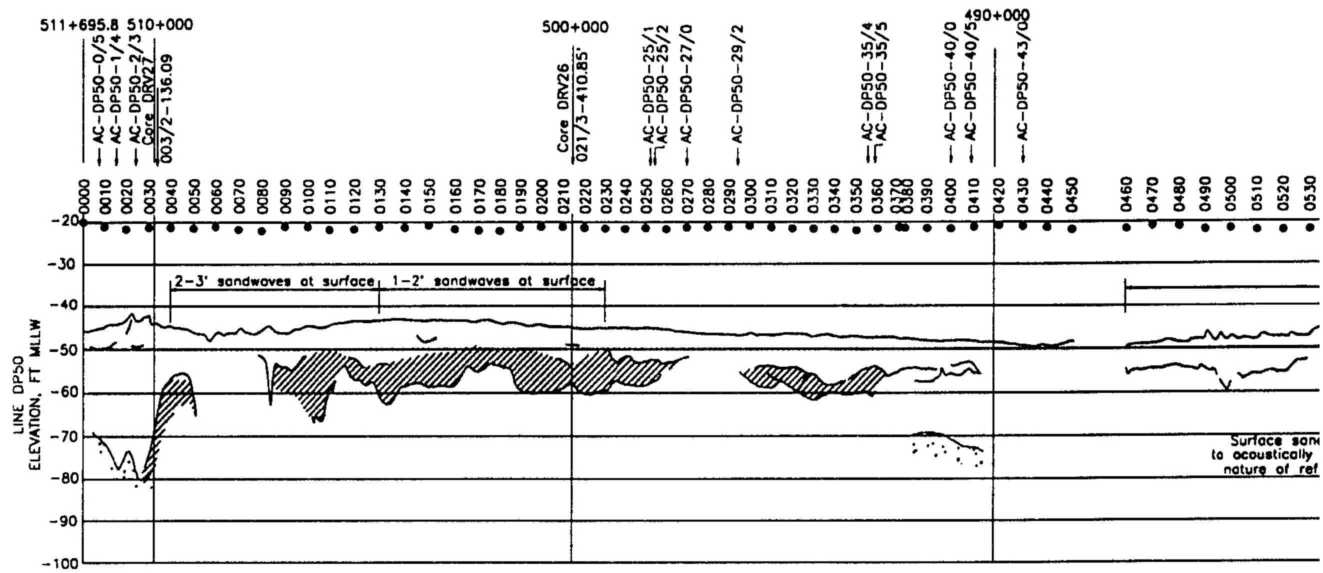
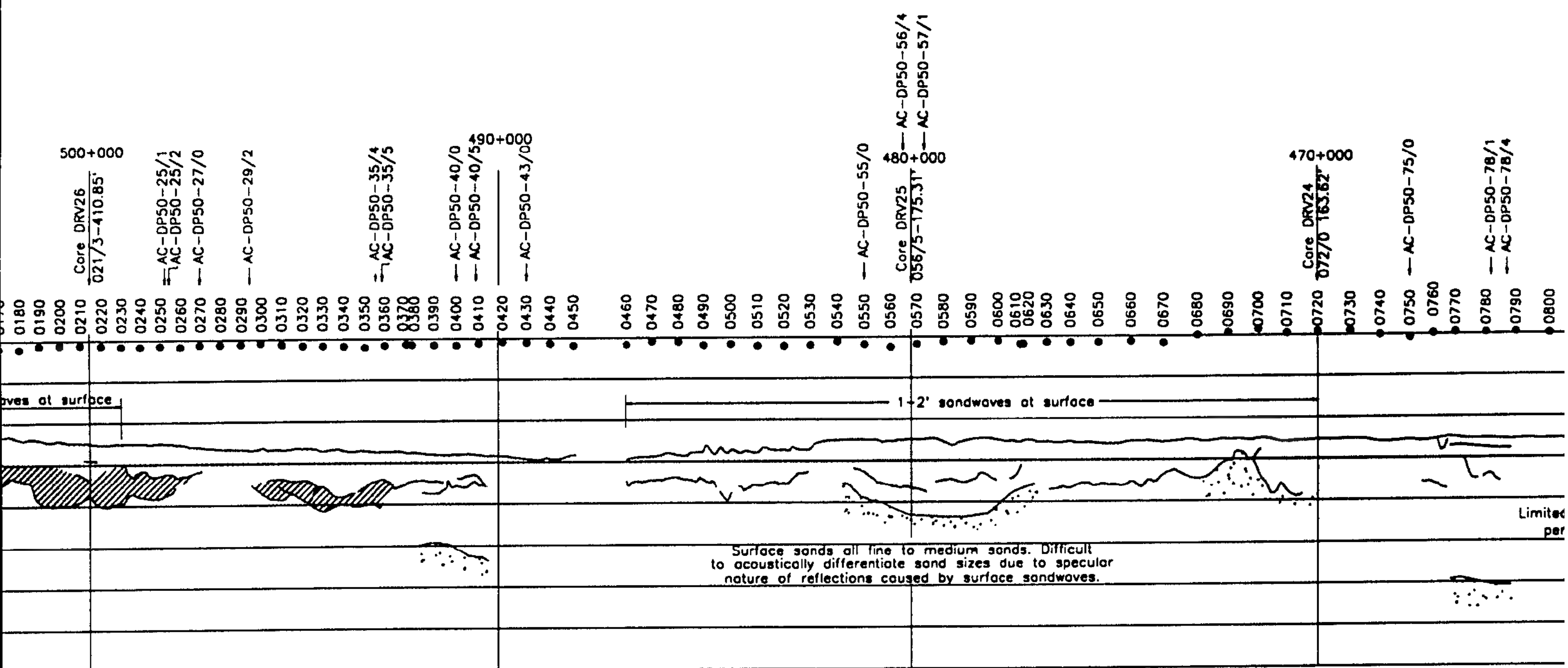
3



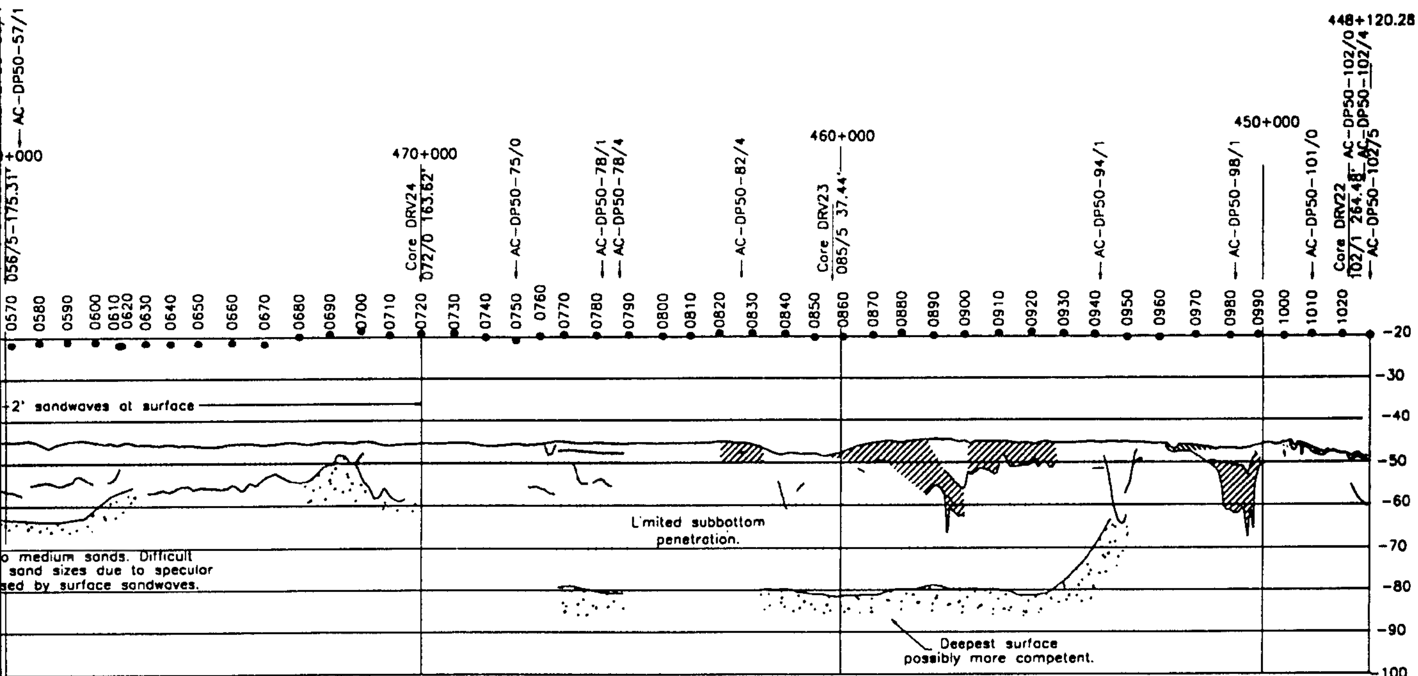
DELAWARE SHIP CH	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2
	> 2.4

(1)



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100



DIMENT DESCRIPTION
Basic Soil Description
Soft Muds, Clays
Clays, Silts Sandy Silt
Clayey Sands Silty Sands
Silty Sands Fine Sands
Medium Sands
Coarse Sands & Gravels Clayey Sands w/ Gravels
Rock, Consolidated Clays

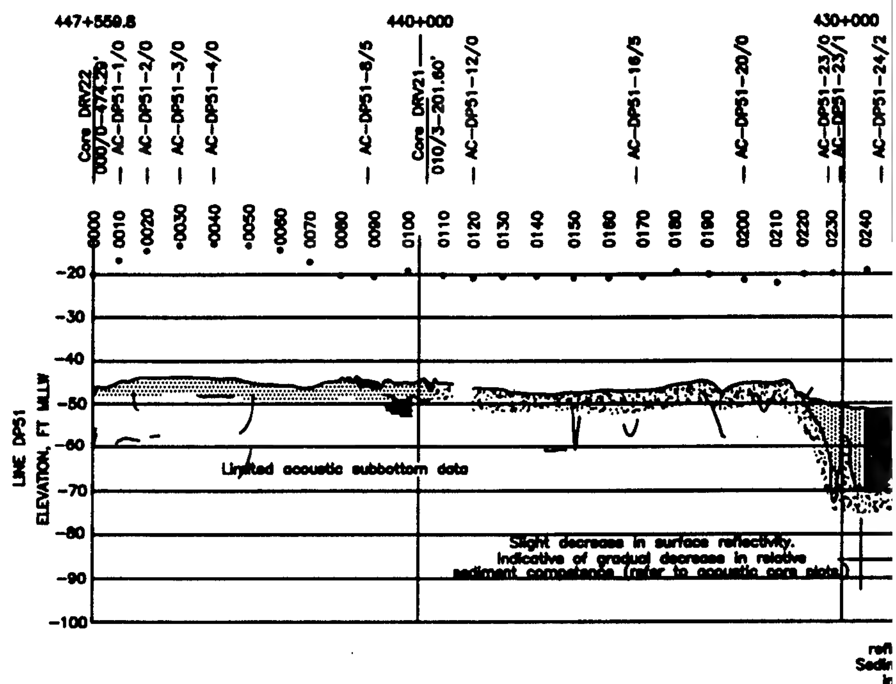
WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

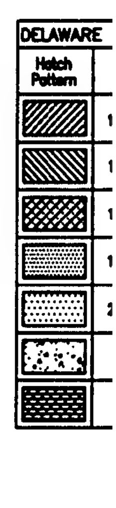
DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE DP50

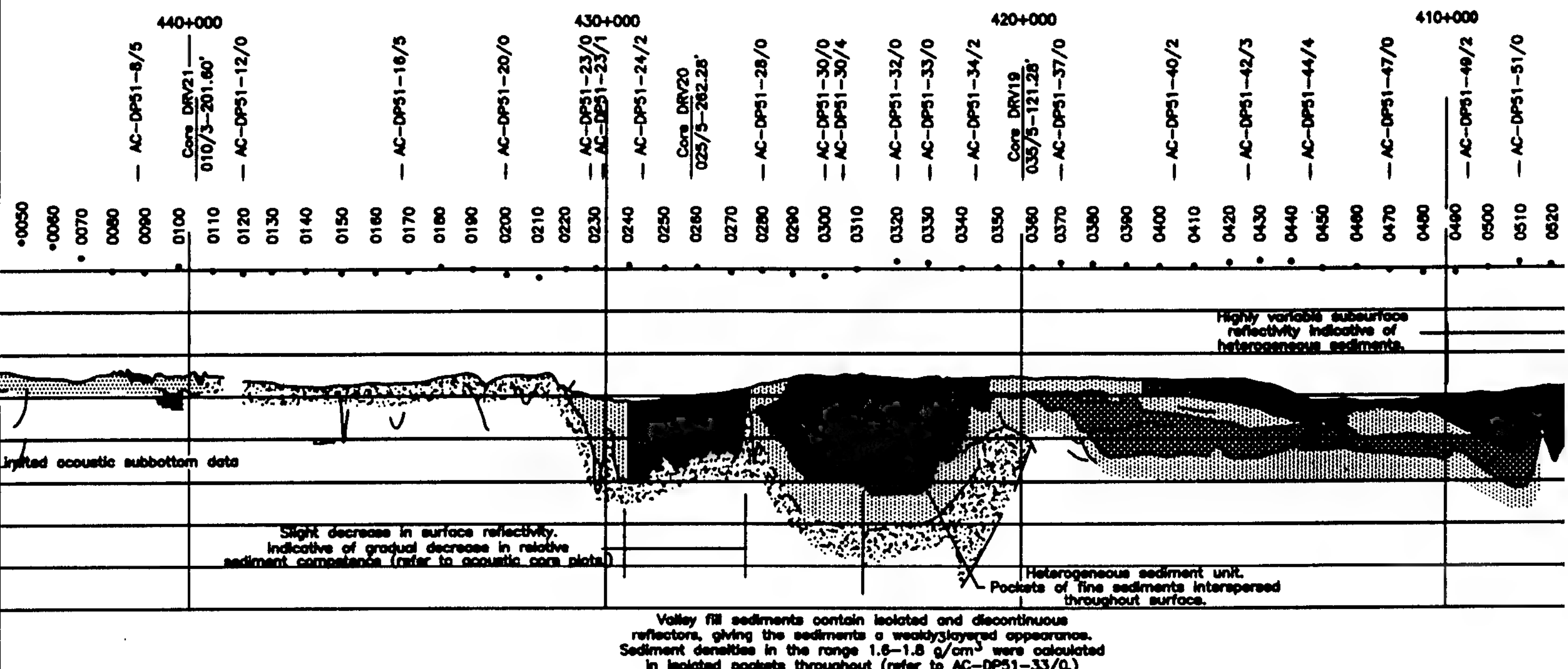
FILE NAME: DP50.DWG

SCALE: 1"=4500' | DATE: NOVEMBER 3, 1995 | PLATE 2

3

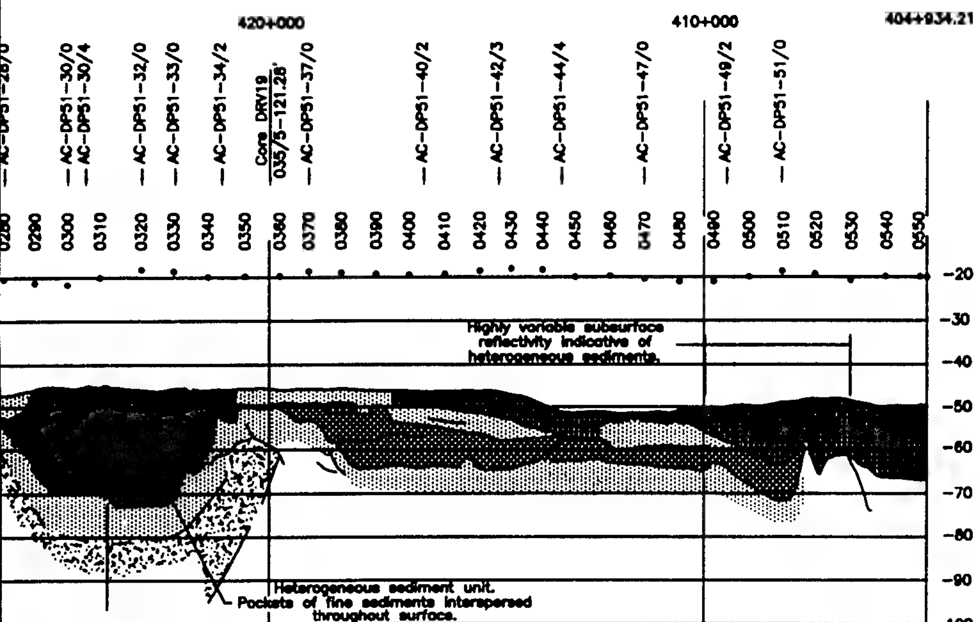

447+559.8
440+000
430+000
Core DRV22
000/0–474.29'
— AC–DP51–1/0
— AC–DP51–2/0
— AC–DP51–3/0
— AC–DP51–4/0
— AC–DP51–8/5
Core DRV21
010/3–201.60'
— AC–DP51–12/0
— AC–DP51–16/5
— AC–DP51–20/0
— AC–DP51–23/0
— AC–DP51–23/1
— AC–DP51–24/2
0000 0010 0020 0030 0040 0050 0060 0070 0080 0090 0100 0110 0120 0130 0140 0150 0160 0170 0180 0190 0200 0210 0220 0230 0240
LINE DP51
ELEVATION, FT MLLW
-20 -30 -40 -50 -60 -70 -80 -90 -100
Limited acoustic subbottom data
Slight decrease in surface reflectivity.
Indicative of gradual decrease in relative
sediment competence (refer to acoustic core plots)


DELAWARE
Hatch Pattern



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, ? m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100



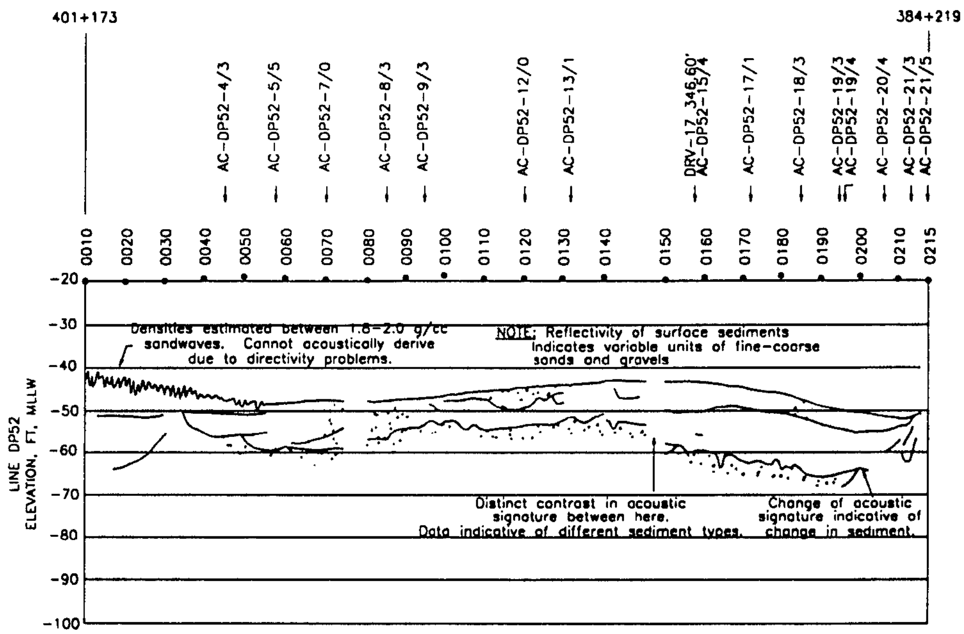
ments contain isolated and discontinuous
the sediments a weakly layered appearance.
in the range 1.6–1.8 g/cm^3 were calculated
ets throughout (refer to AC-DP51-33/0.)

EL SEDIMENT DESCRIPTION	
an Grain ze, ? m	Basic Soil Description
ide Model oundary	Soft Muds, Clays
> 4	Clays, Silts Sandy Silt
– 2.2	Clayey Sands Silty Sands
– 1.2	Silty Sands Fine Sands
2 – 0	Medium Sands
> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
N/A	Rock, Consolidated Clays

= 100

(3)

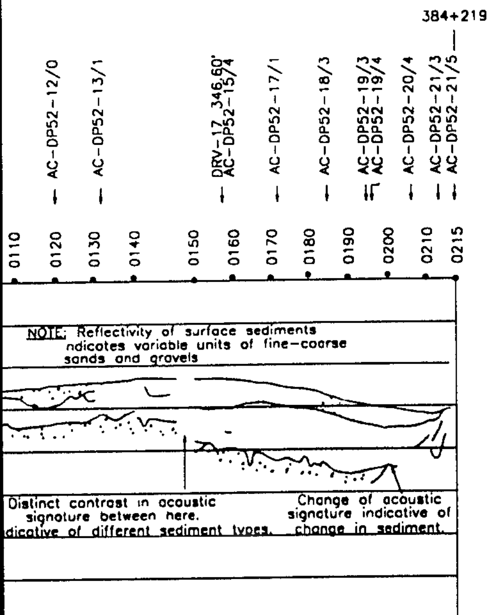
WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE MAIN CHANNEL SEDIMENT PROFILE LINE DP51		
FILE NAME: DP51.DWG		
SCALE: 1"=4500'	DATE: NOVEMBER 3, 1995	PLATE 3



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

(1)



SEDIMENT DESCRIPTION	
rain m	Basic Soil Description
odel ry	Soft Muds, Clays
	Clays, Silts Sandy Silt
2	Clayey Sands Silty Sands
2	Silty Sands Fine Sands
0	Medium Sands
	Coarse Sands & Gravels Clayey Sands w/ Gravels
	Rock, Consolidated Clays

100

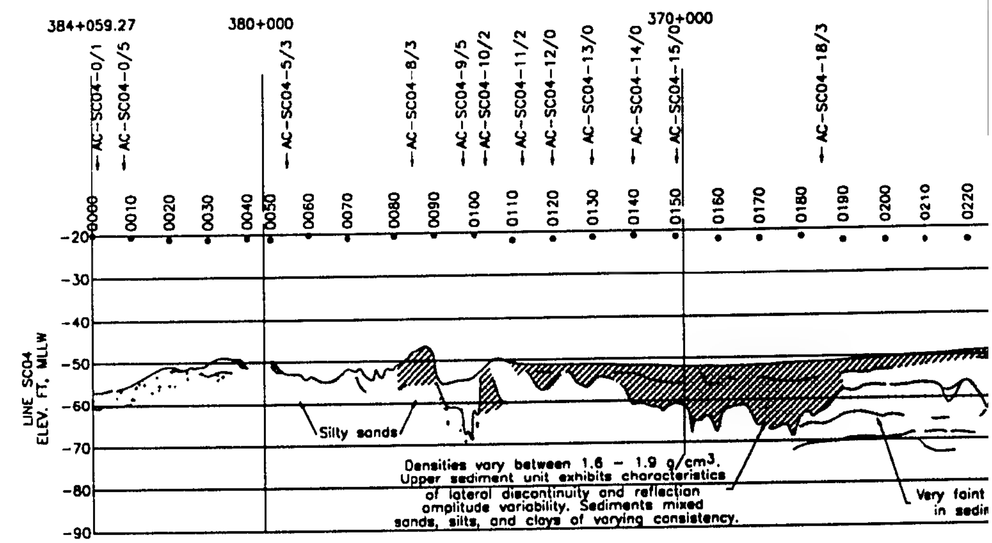
2

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE DP52

FILE NAME: DP50.DWG

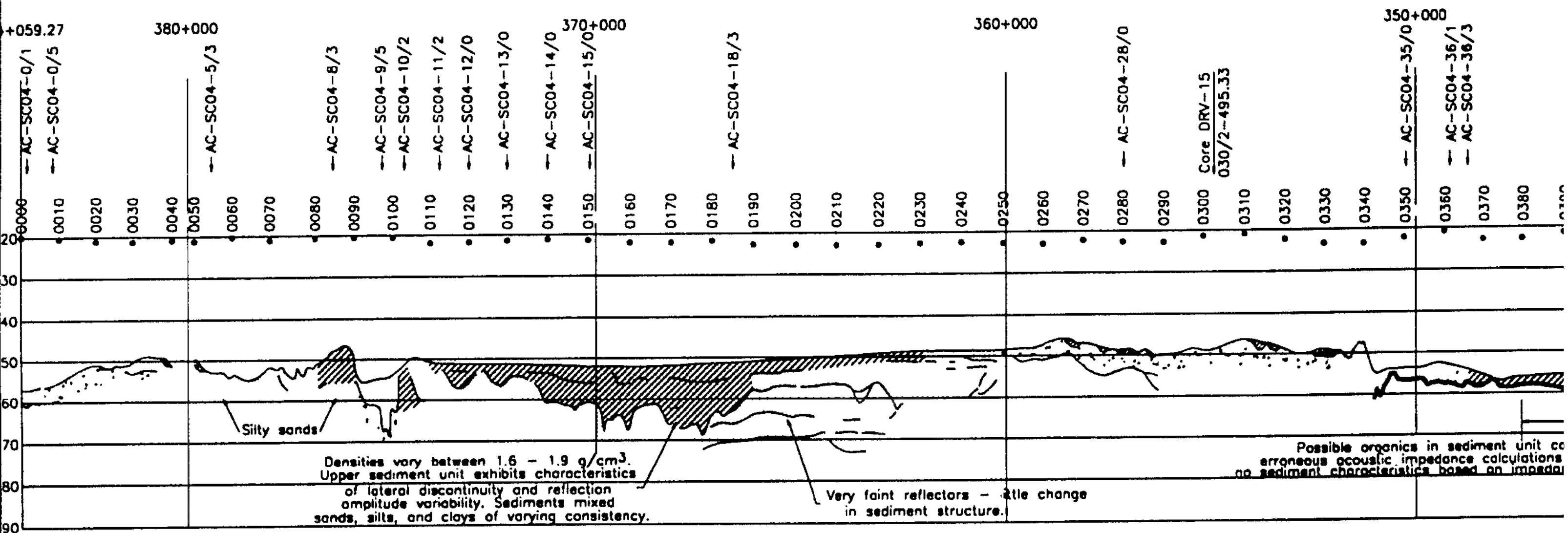
SCALE: 1"=4500' | DATE: NOVEMBER 3, 1995 | PLATE 4



DELAWARE SHIP CHANNEL SEDIMEN			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	
	1.0 – 1.4	Outside Model Boundary	Soft
	1.4 – 1.6	> 4	Clays, Sandy
	1.6 – 1.8	4 – 2.2	Clayey Silty
	1.8 – 2.0	2.2 – 1.2	Silty Fine
	2.0 – 2.2	1.2 – 0	Mediu
	> 2.2	> 0	Coars Clayey
	> 2.4	N/A	Rock,

V.E. = 100

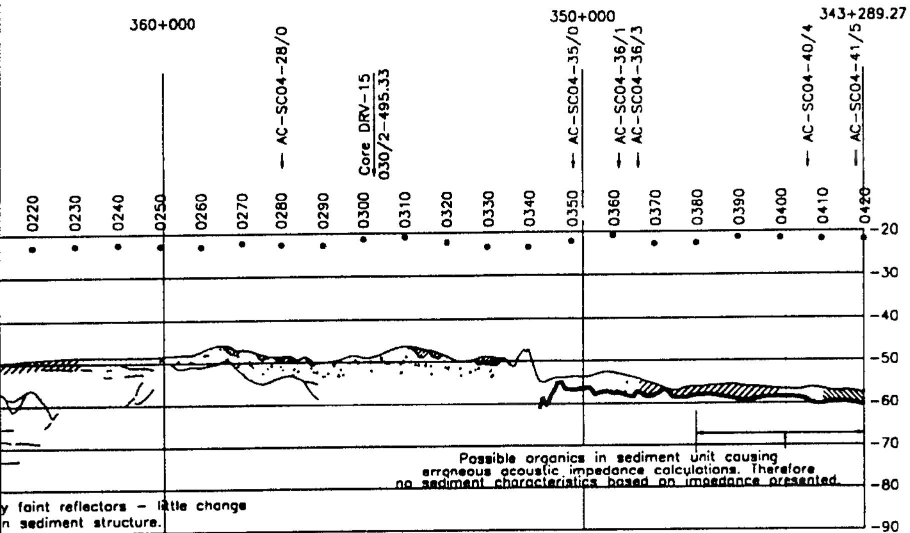
1



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 – 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 – 1.6	> 4	Clays, Silts Sandy Silt
	1.6 – 1.8	4 – 2.2	Clayey Sands Silty Sands
	1.8 – 2.0	2.2 – 1.2	Silty Sands Fine Sands
	2.0 – 2.2	1.2 – 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

2



DIMENT DESCRIPTION
Basic Soil Description
Soft Muds, Clays
Clays, Silts Sandy Silt
Clayey Sands Silty Sands
Silty Sands Fine Sands
Medium Sands
Coarse Sands & Gravels Clayey Sands w/ Gravels
Rock, Consolidated Clays

0

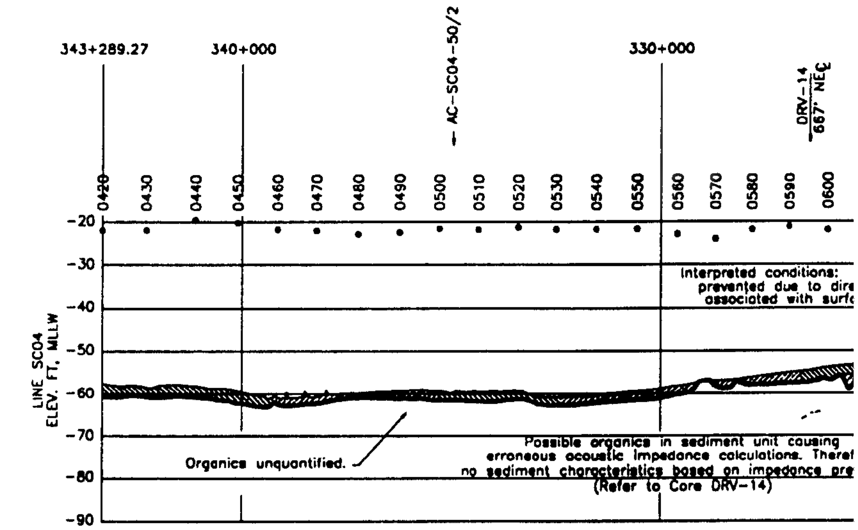
3

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC04A FILES 0/0 – 42/0

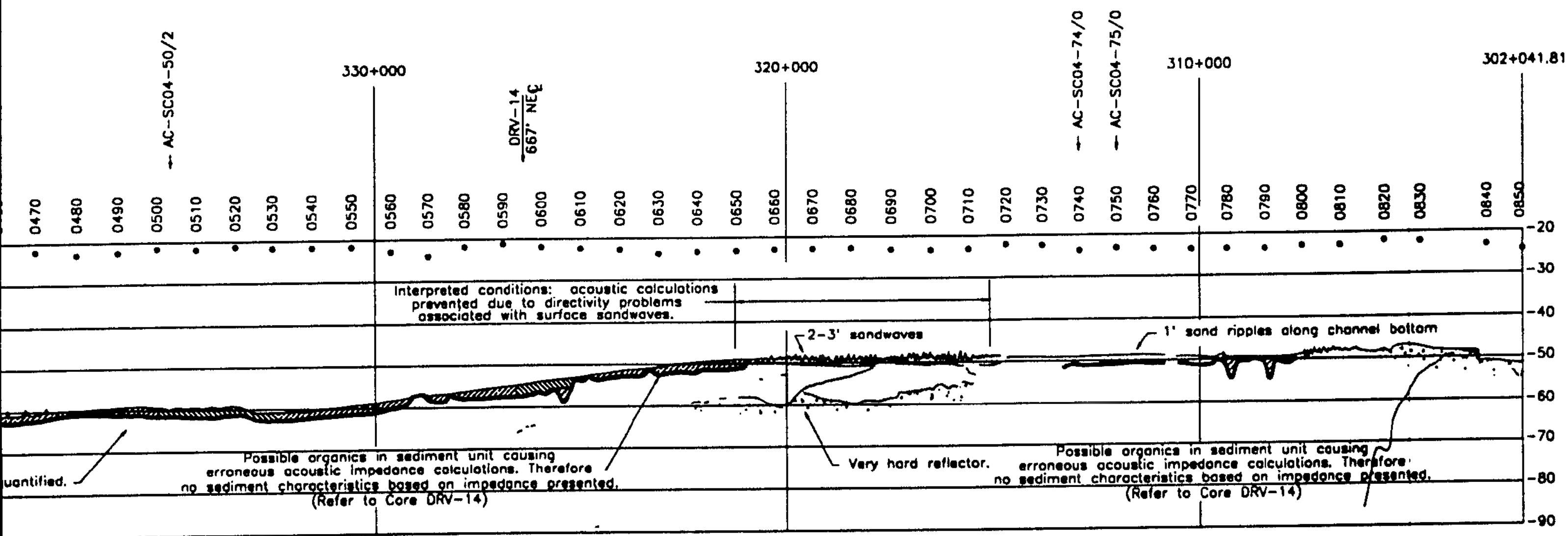
FILE NAME: SC04A.DWG

SCALE: 1"=4500'	DATE: NOVEMBER 3, 1995	PLATE 5



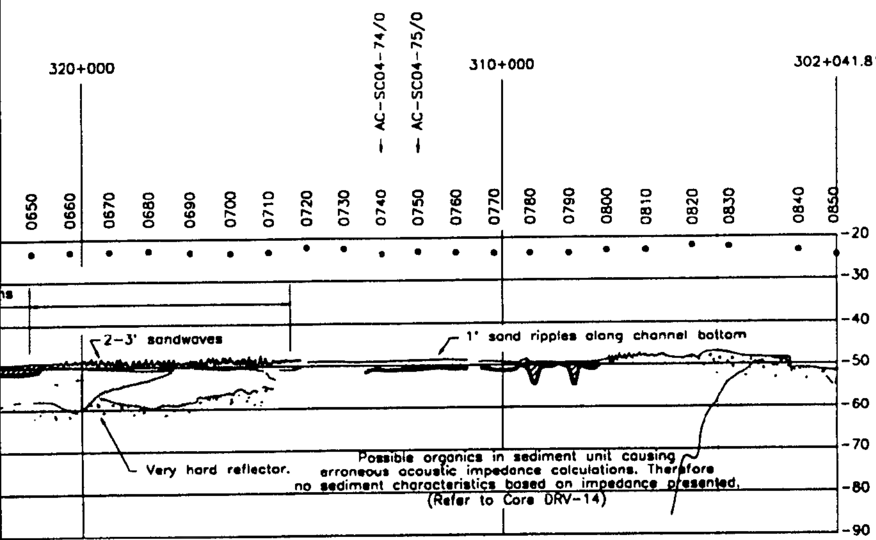
DELAWARE SHIP C	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2
	> 2.4

1



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100



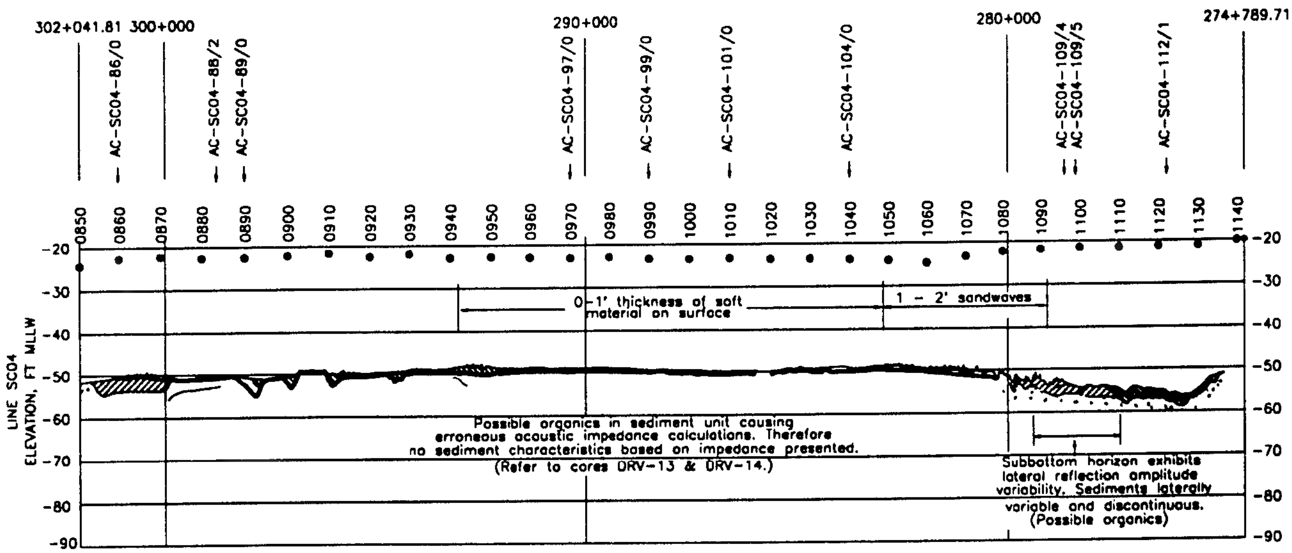
NT DESCRIPTION
Basic Soil Description
Muds, Clays
s, Silts dy Silt
ey Sands Sands
Sands Sands
ium Sands
rse Sands & Gravels ey Sands w/ Gravels
k, Consolidated Clays

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC04B FILES 042/0 – 085/0

FILE NAME: SC04B.DWG		
SCALE: 1"=4500'	DATE: NOVEMBER 3, 1995	PLATE 6

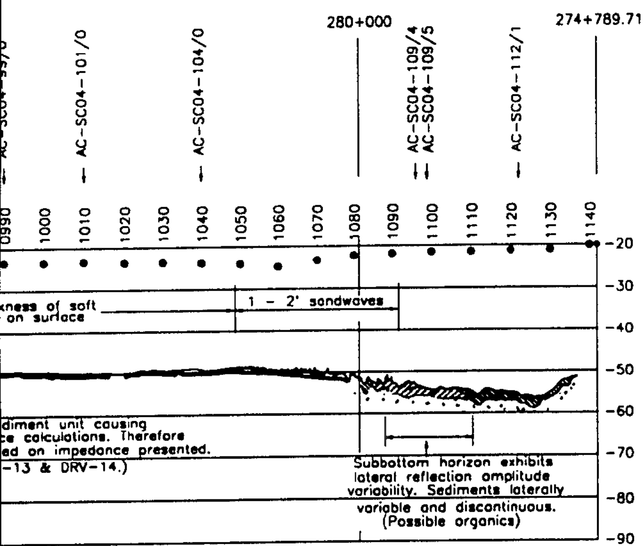
3



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

1

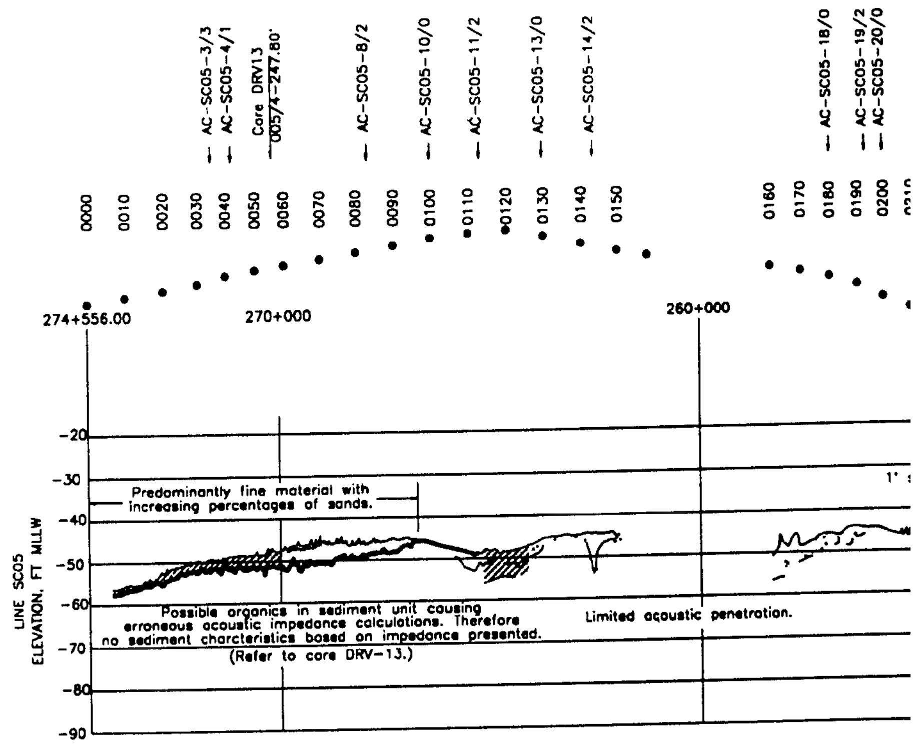


SEDIMENT DESCRIPTION	
Grain m	Basic Soil Description
Model ory	Soft Muds, Clays
	Clays, Silts Sandy Silt
.2	Clayey Sands Silty Sands
1.2	Silty Sands Fine Sands
0	Medium Sands
	Coarse Sands & Gravels Clayey Sands w/ Gravels
	Rock, Consolidated Clays

100

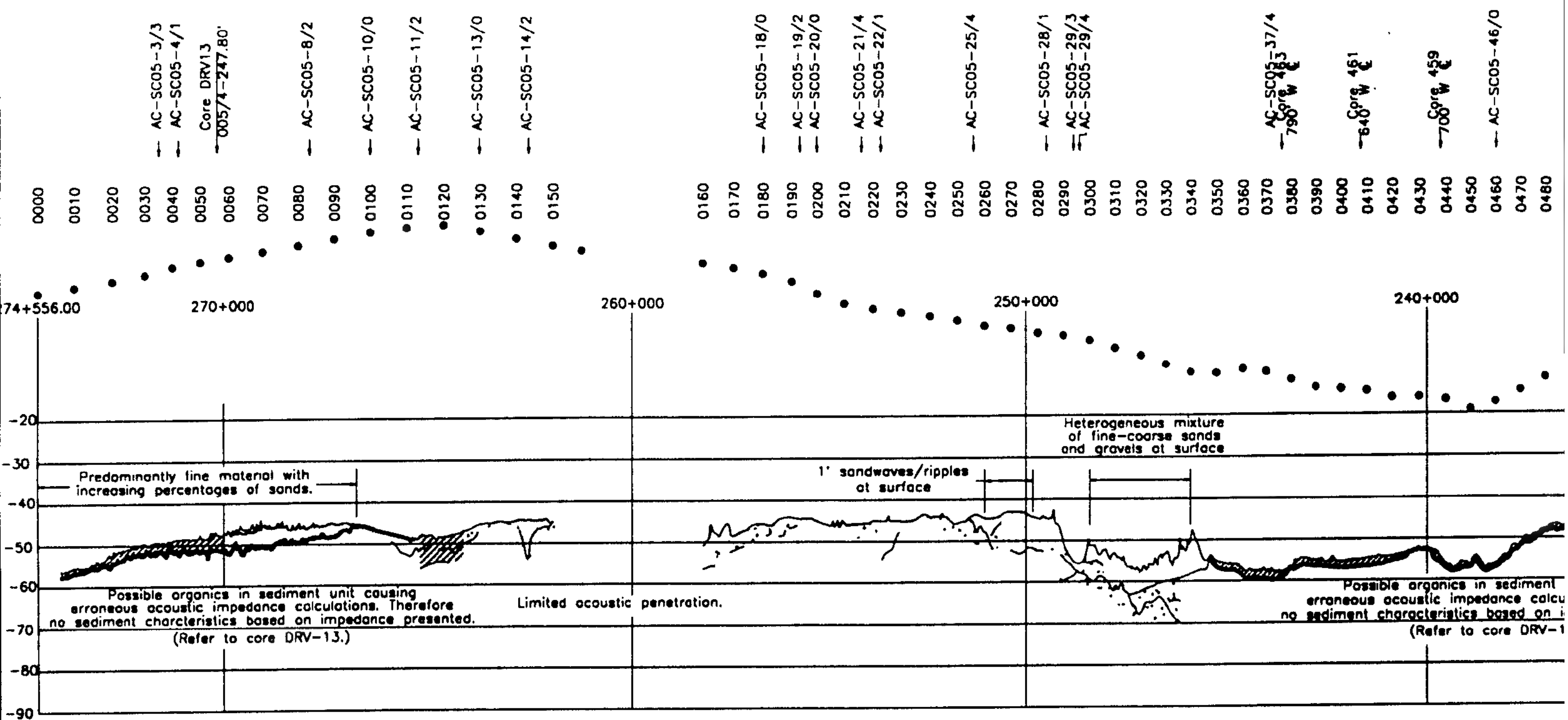
2

WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180
DELAWARE MAIN CHANNEL SEDIMENT PROFILE LINE SC04C FILES 085/0 - 114/3
FILE NAME: SC04C.DWG
SCALE: 1"=4500' | DATE: NOVEMBER 6, 1995 | PLATE 7



DELAWARE SHIP CHANNEL		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	>
	> 2.4	N/

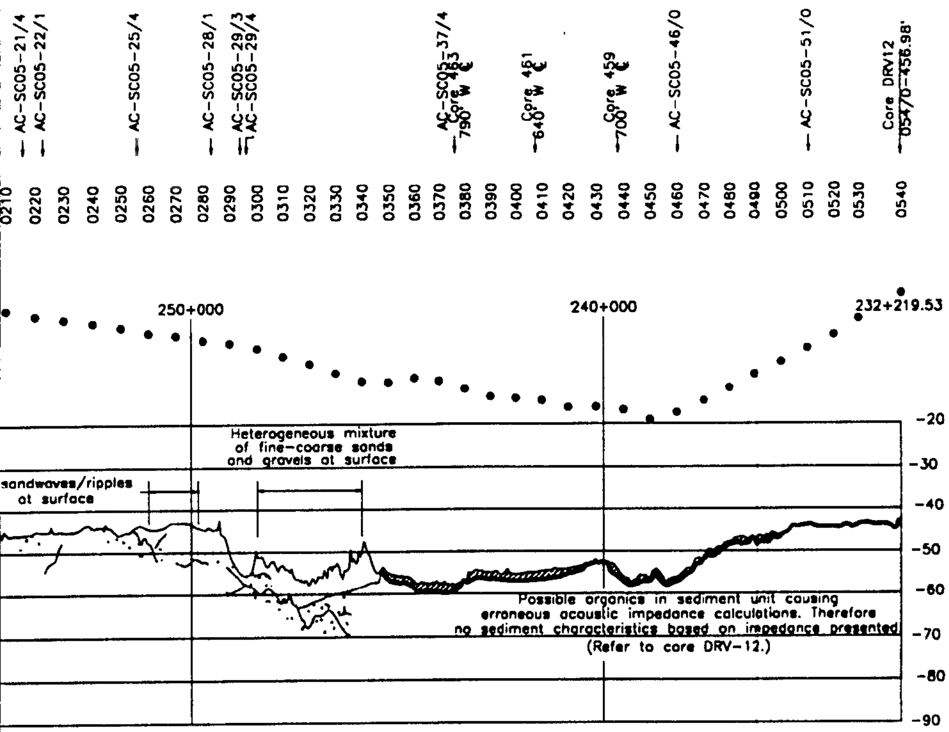
V.E. =



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

2



SEDIMENT DESCRIPTION	
Grain Φ m	Basic Soil Description
Model dory	Soft Muds, Clays
	Clays, Silts Sandy Silt
2.2	Clayey Sands Silty Sands
1.2	Silty Sands Fine Sands
0	Medium Sands
	Coarse Sands & Gravels Clayey Sands w/ Gravels
	Rock, Consolidated Clays

100

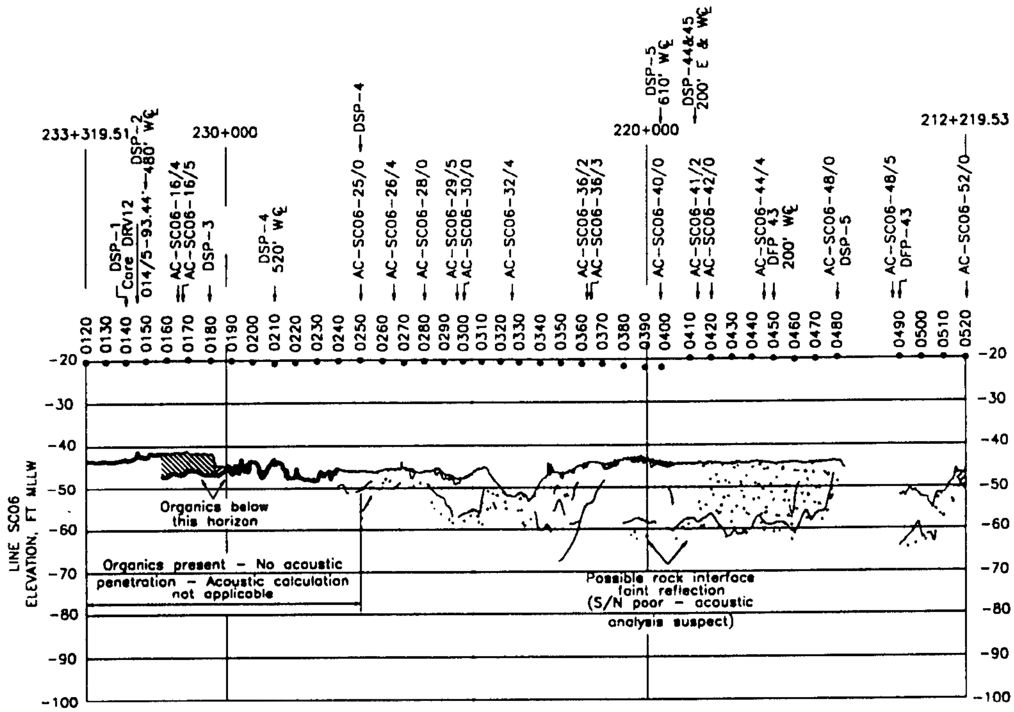
3

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC05

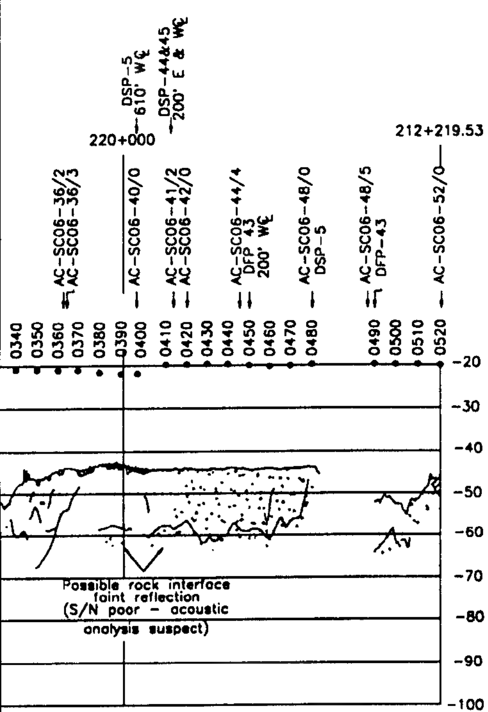
FILE NAME: SC05.DWG

SCALE: 1"=4500' | DATE: NOVEMBER 8, 1995 | PLATE 8



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100



EDIMENT DESCRIPTION	
n n	Basic Soil Description
el	Soft Muds, Clays
	Clays, Silts Sandy Silt
	Clayey Sands Silty Sands
	Silty Sands Fine Sands
	Medium Sands
	Coarse Sands & Gravels Clayey Sands w/ Gravels
	Rock, Consolidated Clays

00

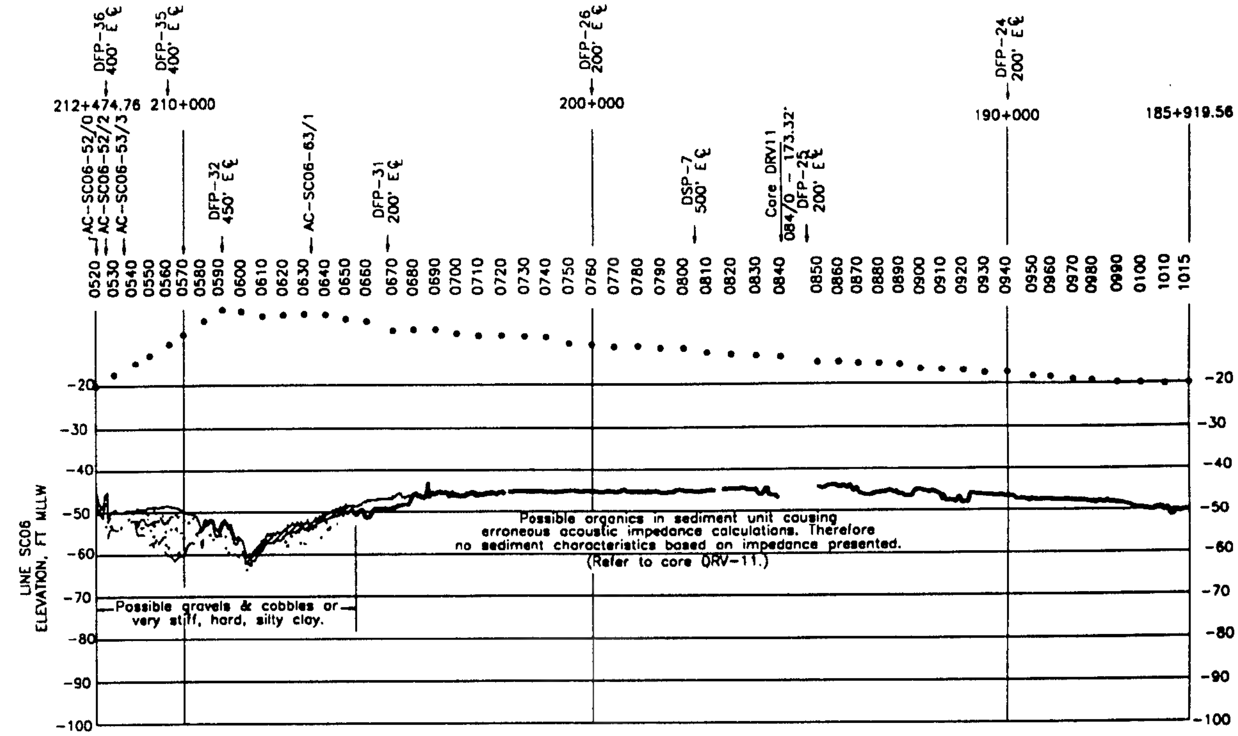
2

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 0/0–52/0

FILE NAME: SC06A.DWG

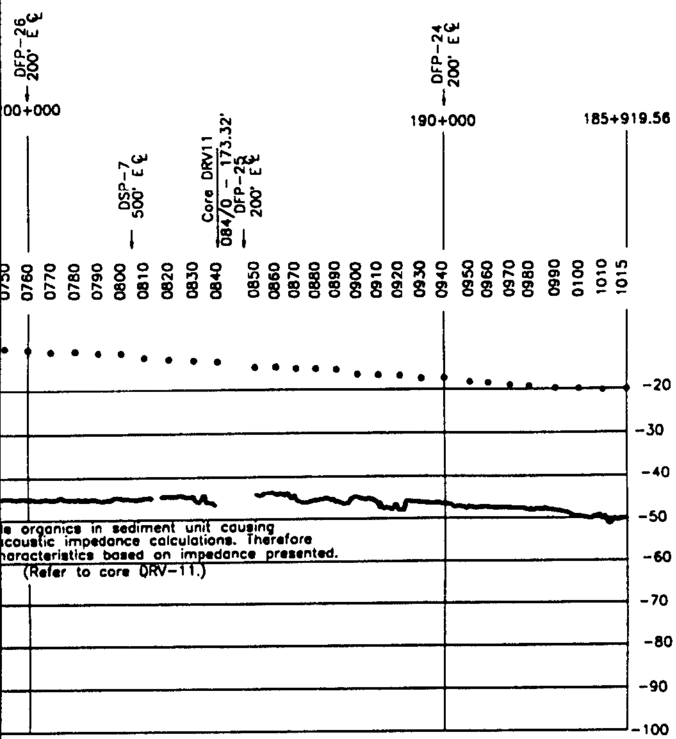
SCALE: 1"=4500'	DATE: NOVEMBER 6, 1995	PLATE 9



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

1

V.E. = 100



EL SEDIMENT DESCRIPTION	
an Grain ze, Φ m	Basic Soil Description
side Model oundary	Soft Muds, Clays
> 4	Clays, Silts Sandy Silt
- 2.2	Clayey Sands Silty Sands
- 1.2	Silty Sands Fine Sands
2 - 0	Medium Sands
> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
N/A	Rock, Consolidated Clays

= 100

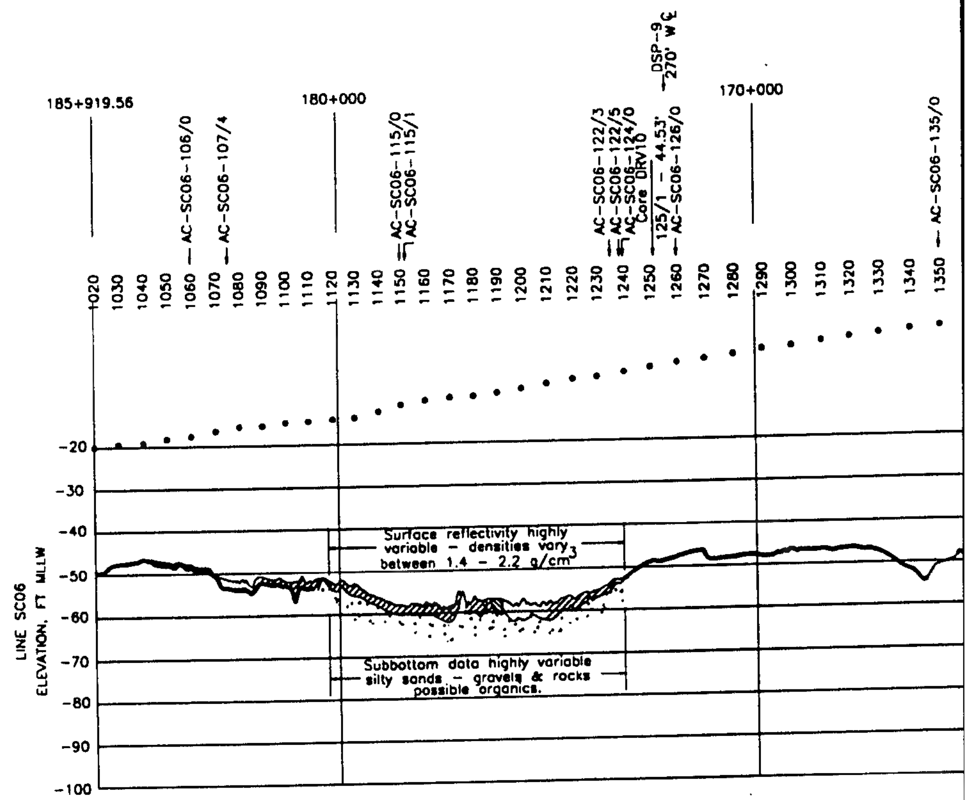
2

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 52/0-102/0

FILE NAME: SC06B.DWG

SCALE: 1"=4500' | DATE: NOVEMBER 6, 1994 | PLATE 10

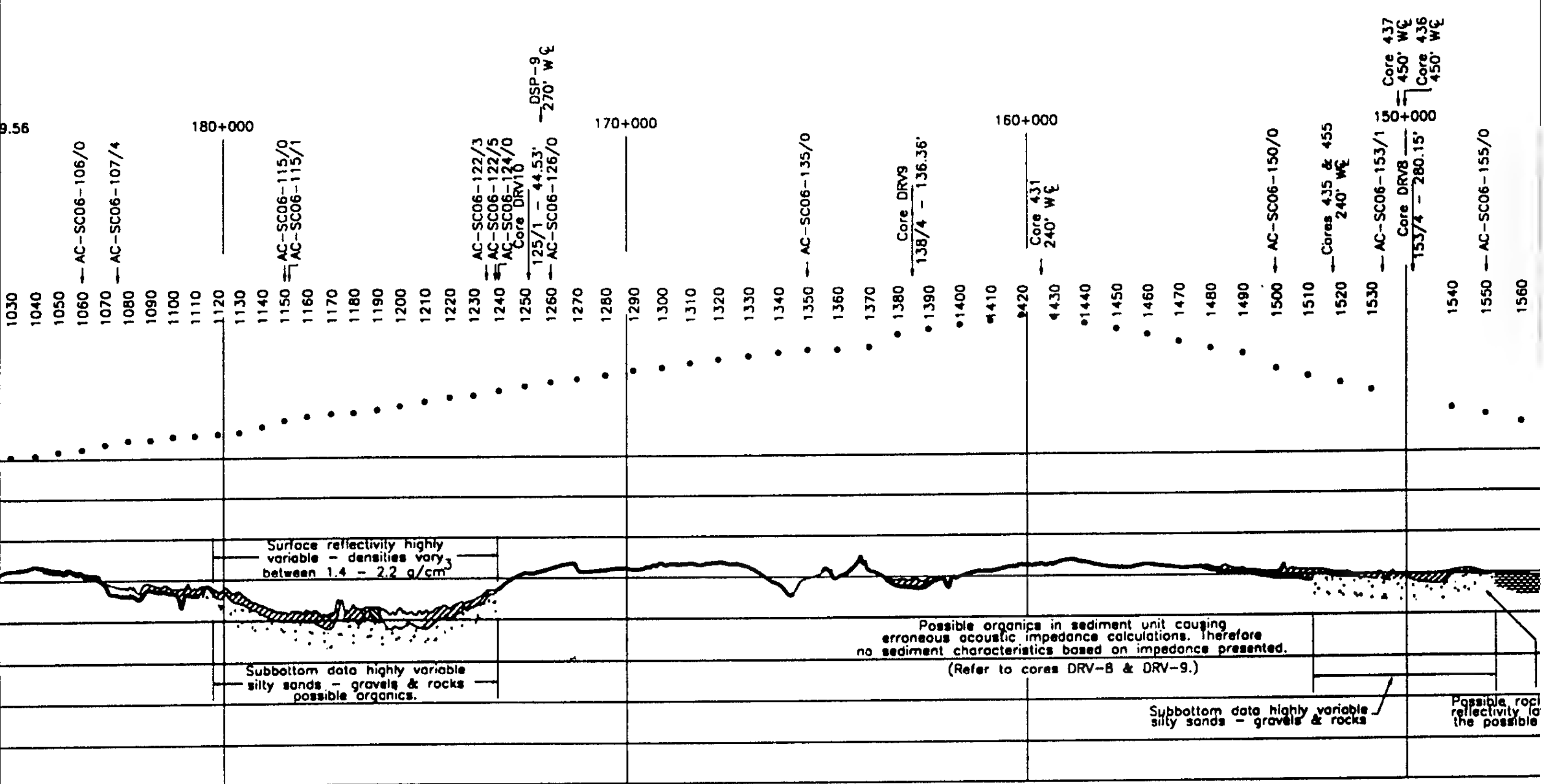


Note: No core verification of top of rock surfaces.

DELAWARE SHIP CHANNEL SE		
Hatch Pattern	Density gm/cc	Mean Grai Size, ф m
	1.0 - 1.4	Outside Mod Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	> 0
	> 2.4	N/A

V.E. = 1

1

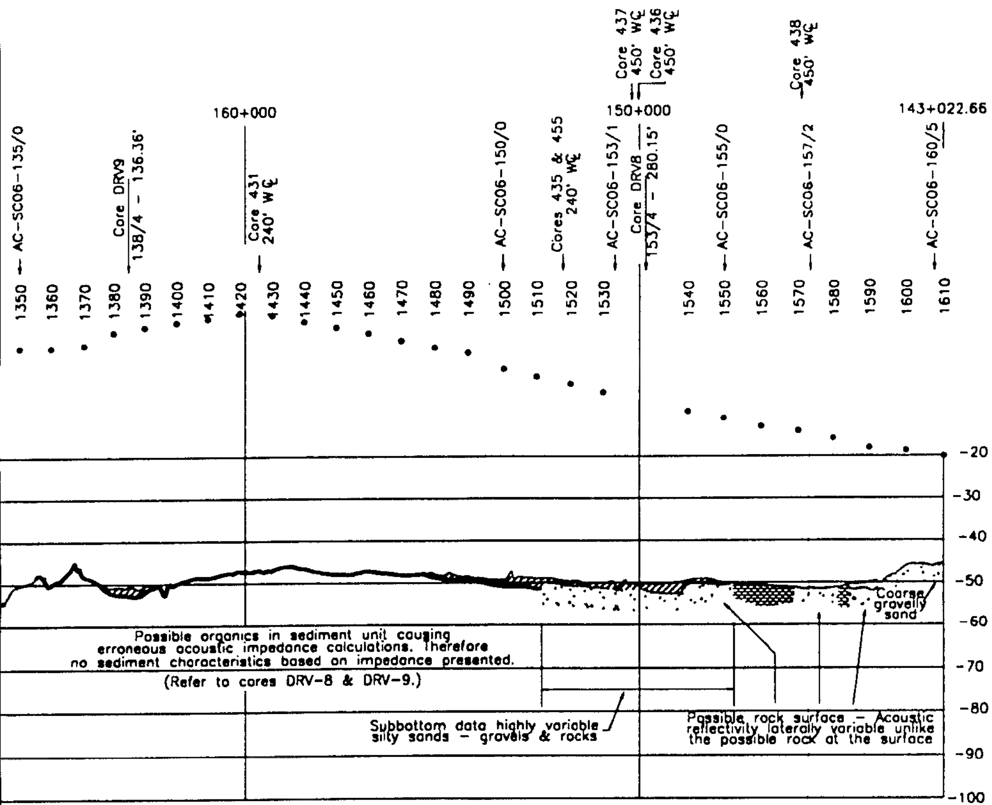


Note: No core verification of top of rock surfaces.

DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, ϕ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

2



SEDIMENT DESCRIPTION	
Grain ϕ m	Basic Soil Description
Model ndary	Soft Muds, Clays
4	Clays, Silts Sandy Silt
2.2	Clayey Sands Silty Sands
1.2	Silty Sands Fine Sands
- 0	Medium Sands
0	Coarse Sands & Gravels Clayey Sands w/ Gravels
/A	Rock, Consolidated Clays

- 100

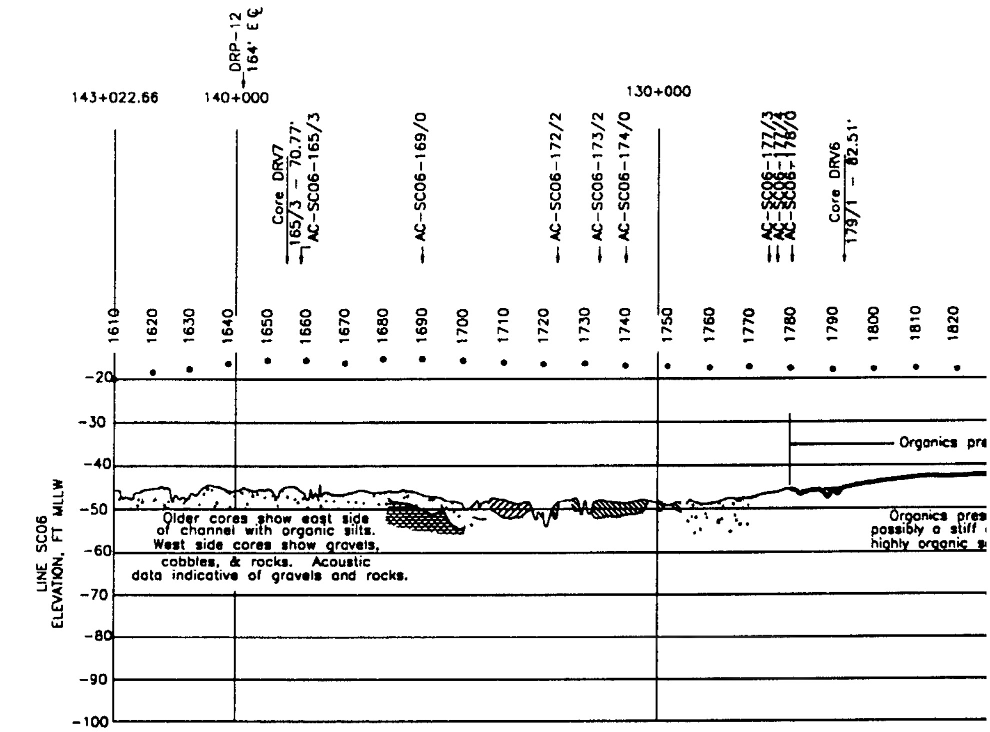
3

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 102/0-161/0

FILE NAME: SC06C.DWG

SCALE: 1"=4500' | DATE: NOVEMBER 6, 1995 | PLATE 11



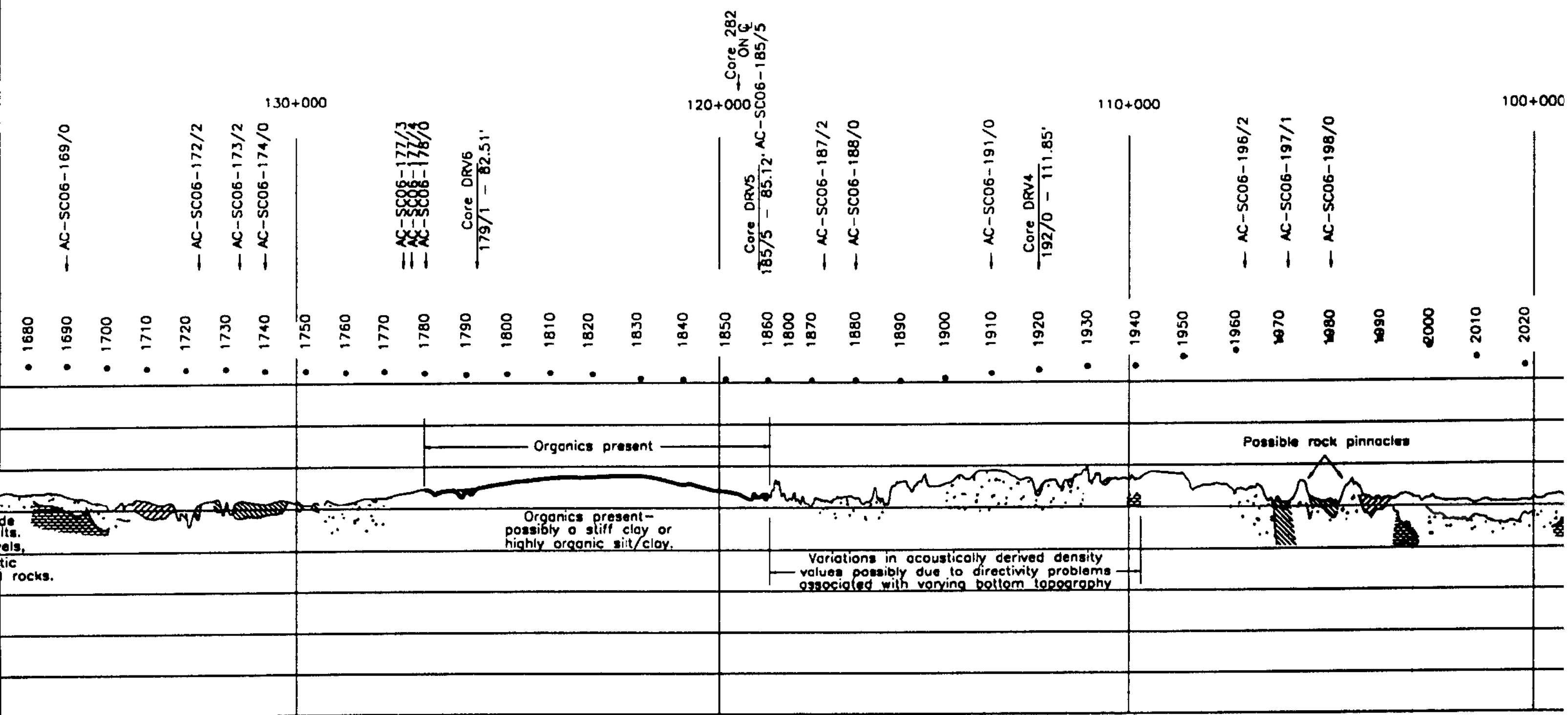
NOTE: Rock detected in cores DR
at approximately elevation

NOTE: East side of center line a
West side of center line a

DELAWARE SHIP CHANN		
Hatch Pattern	Density gm/cc	Me Siz
	1.0 - 1.4	Outs B
	1.4 - 1.6	
	1.6 - 1.8	4
	1.8 - 2.0	2.2
	2.0 - 2.2	1.1
	> 2.2	
	> 2.4	

V.E.

1

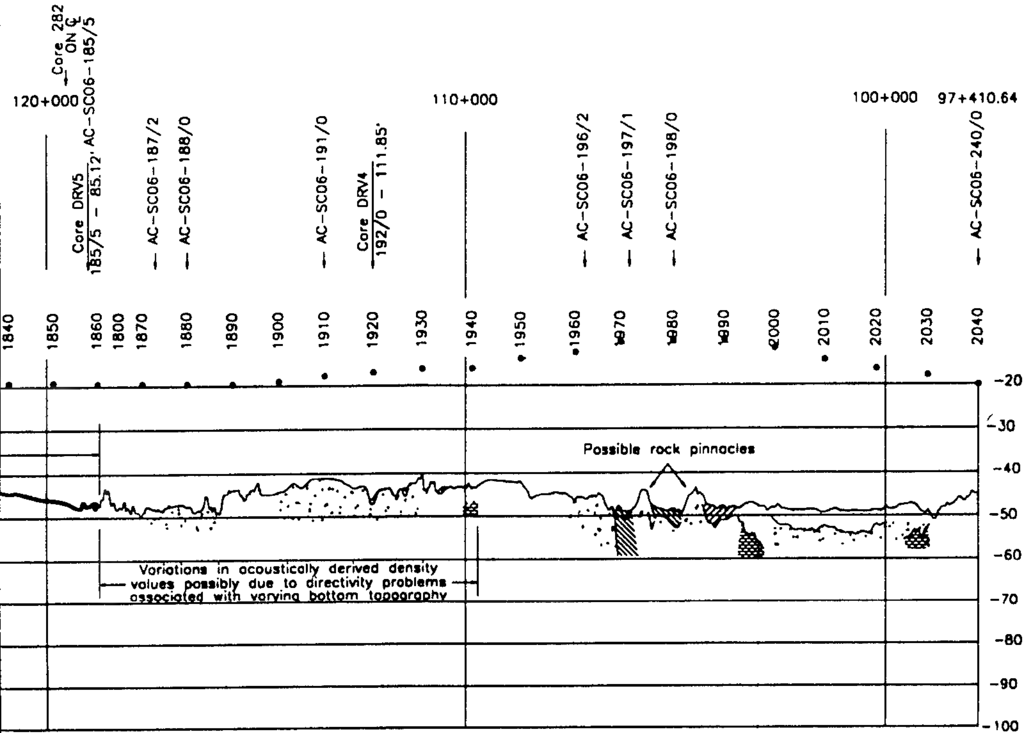


NOTE: Rock detected in cores DRV-7, DRV-5, and DRV-4 at approximately elevation -49.

NOTE: East side of center line contains organics. West side of center line contains sands, gravels, and rocks.

DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100



RV-5, and DRV-4

organics.
sands, gravels, and rocks.

DIMENT DESCRIPTION
Basic Soil Description
Soft Muds, Clays
Clays, Silts Sandy Silt
Clayey Sands Silty Sands
Silty Sands Fine Sands
Medium Sands
Coarse Sands & Gravels Clayey Sands w/ Gravels
Rock, Consolidated Clays

0

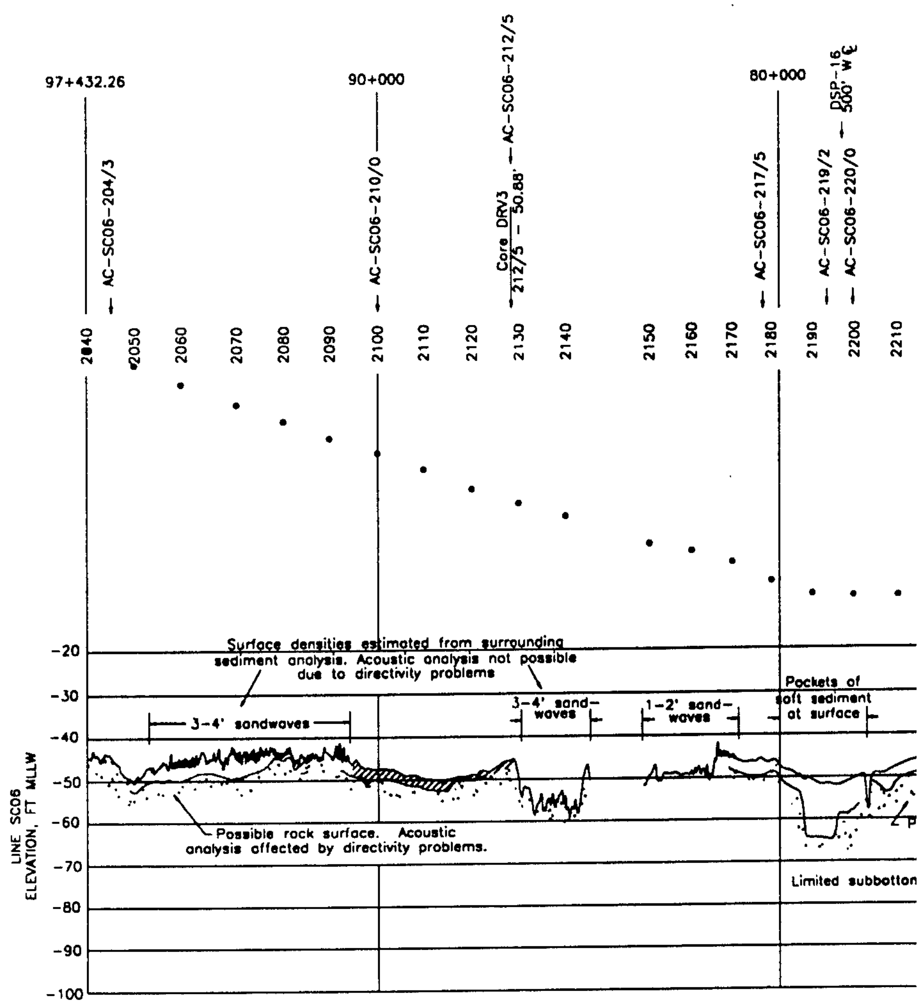
3

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 161/0–204/0

FILE NAME: SC06D.DWG

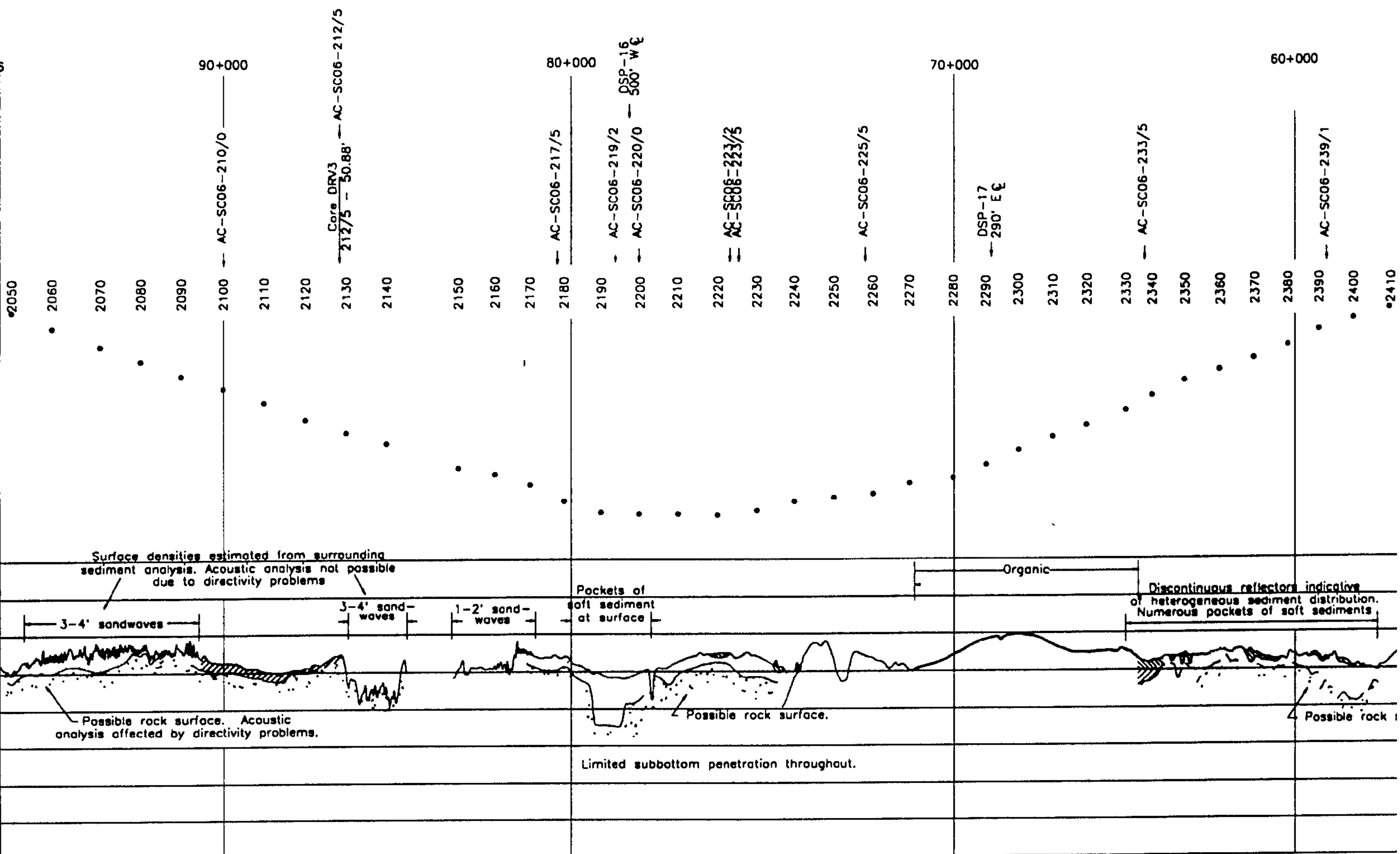
SCALE: 1"=4500' | DATE: NOVEMBER 6, 1994 | PLATE 12



DELAWARE SHIP CHANNEL SE		
Hatch Pattern	Density gm/cc	Mean Grai Size, Φ r
	1.0 - 1.4	Outside Mod Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	> 0
	> 2.4	N/A

V.E. = 1

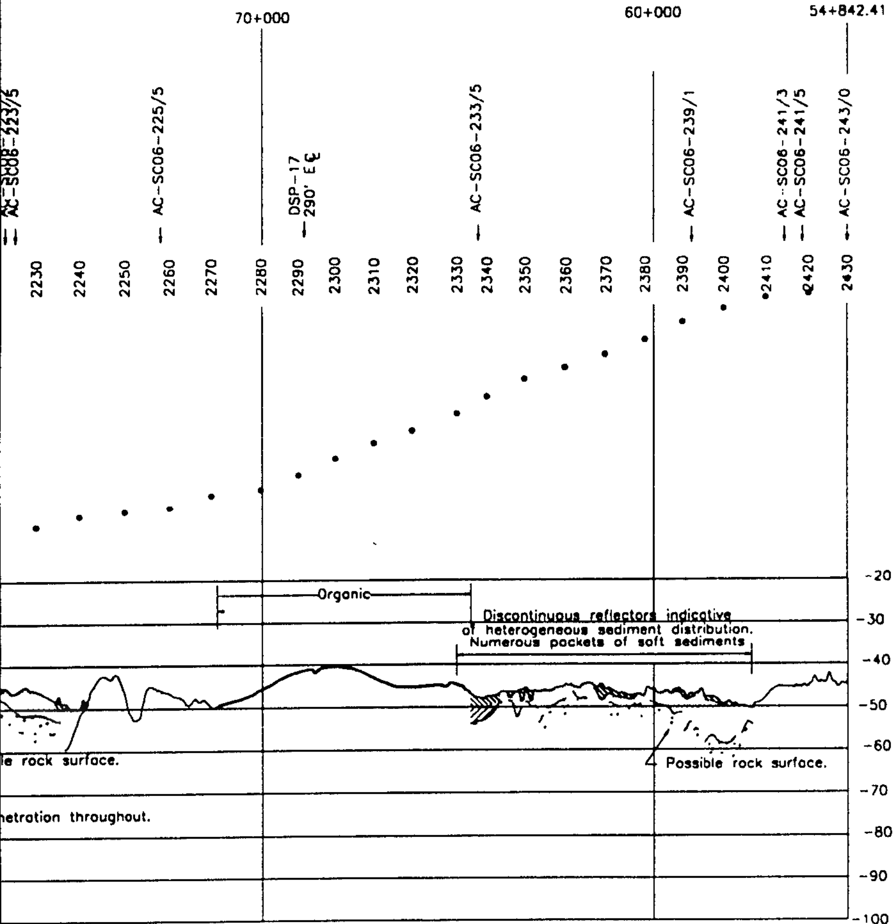
1



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

2



ENT DESCRIPTION
Basic Soil Description
oft Muds, Clays
ays, Silts andy Silt
ayey Sands lty Sands
lty Sands ne Sands
edium Sands
oarse Sands & Gravels ayey Sands w/ Gravels
ock, Consolidated Clays

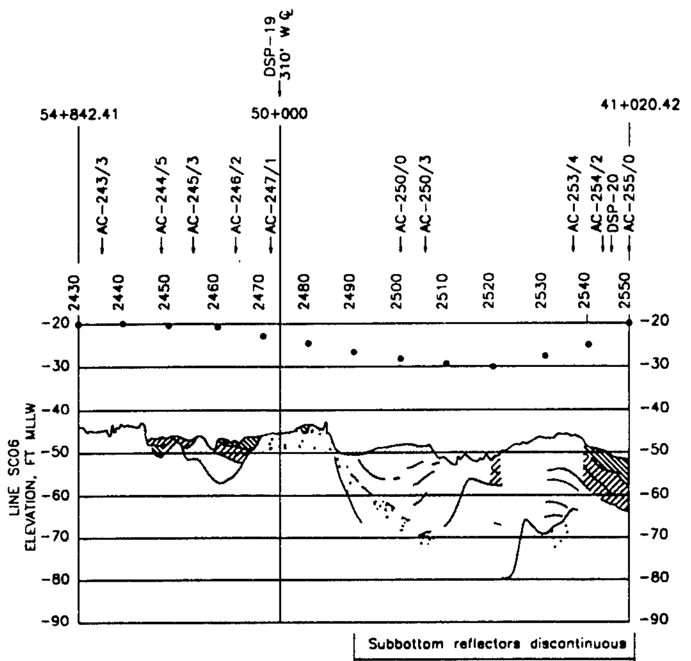
WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 204/0-243/0

FILE NAME: SC06E.DWG

SCALE: 1"=4500' | DATE: NOVEMBER 6, 1995 | PLATE 13

3



Note: Many horizons have low reflectivity values indicative of only subtle changes in sediment structure.

DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, ϕ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

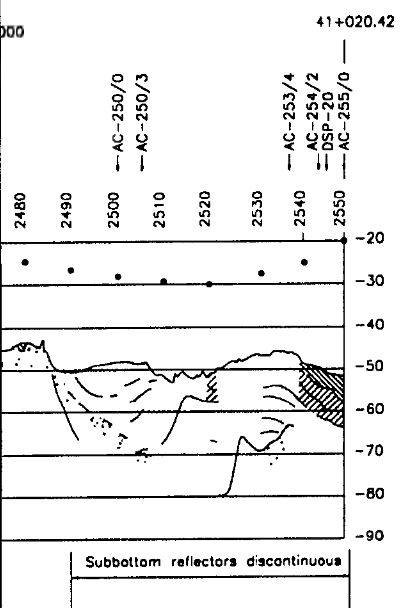
1

W/

LI

FILE NAME

SCALE: 1"



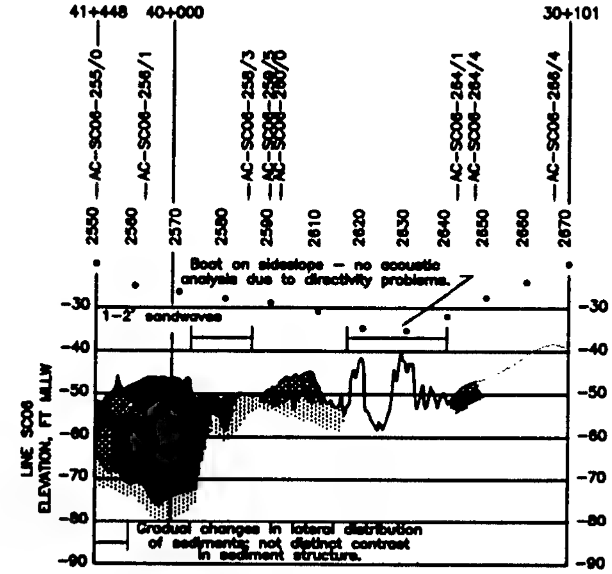
Note: Many horizons have low reflectivity values indicative of only subtle changes in sediment structure.

SEDIMENT DESCRIPTION	
Grain Φ m	Basic Soil Description
Model ndary	Soft Muds, Clays
4	Clays, Silts Sandy Silt
2.2	Clayey Sands Silty Sands
1.2	Silty Sands Fine Sands
- 0	Medium Sands
0	Coarse Sands & Gravels Clayey Sands w/ Gravels
A	Rock, Consolidated Clays

= 100

2

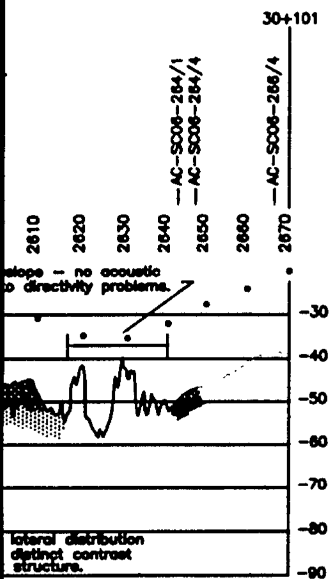
WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180
DELAWARE MAIN CHANNEL SEDIMENT PROFILE LINE SC06, FILES 243/0-255/0
FILE NAME: SC06F.DWG
SCALE: 1"=4500' DATE: NOVEMBER 6, 1995 PLATE 14



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, ? m	Basic Soil Description
	1.0 – 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 – 1.6	> 4	Clays, Silts Sandy Silt
	1.6 – 1.8	4 – 2.2	Clayey Sands Silty Sands
	1.8 – 2.0	2.2 – 1.2	Silty Sands Fine Sands
	2.0 – 2.2	1.2 – 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

1



CHANNEL SEDIMENT DESCRIPTION		
y c	Mean Grain Size, ? m	Basic Soil Description
.4	Outside Model Boundary	Soft Muds, Clays
.6	> 4	Clays, Silts Sandy Silt
.8	4 – 2.2	Clayey Sands Silty Sands
2.0	2.2 – 1.2	Silty Sands Fine Sands
2.2	1.2 – 0	Medium Sands
	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	N/A	Rock, Consolidated Clays

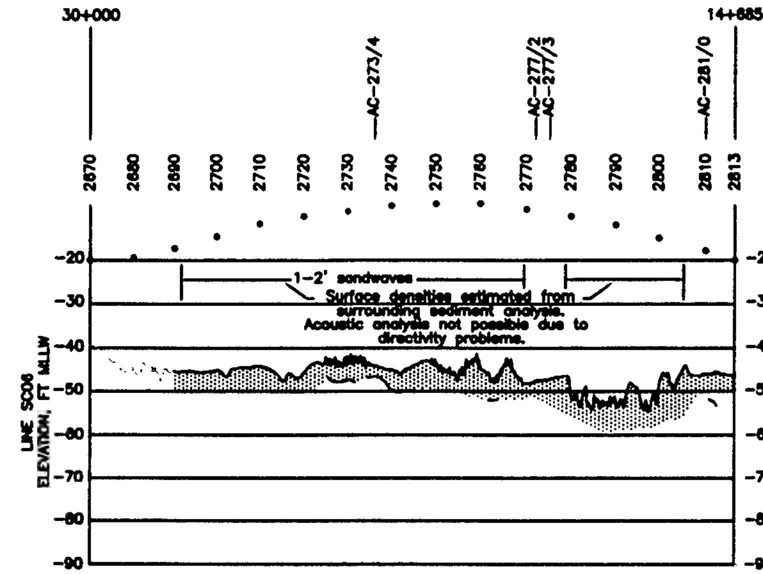
V.E. = 100

2

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 255/0–267/0

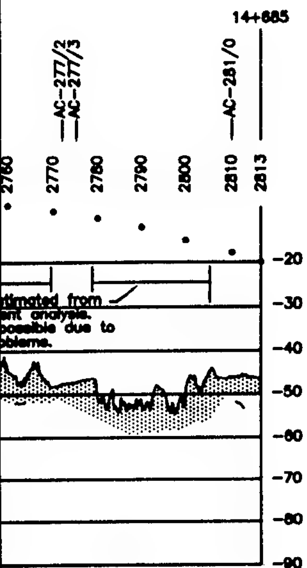
FILE NAME: SC06G.DWG		
SCALE: 1"=4500'	DATE: NOVEMBER 7, 1995	PLATE 15



DELAWARE SHIP CHANNEL SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, ? m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts Sandy Silt
	1.6 - 1.8	4 - 2.2	Clayey Sands Silty Sands
	1.8 - 2.0	2.2 - 1.2	Silty Sands Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	> 0	Coarse Sands & Gravels Clayey Sands w/ Gravels
	> 2.4	N/A	Rock, Consolidated Clays

V.E. = 100

1



DESCRIPTION
Basic Soil Description
...ds, Clays
Silts Silt
Sands ...ands
...ands ...ands
... Sands
... Sands & Gravels Sands w/ Gravels
Consolidated Clays

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE MAIN CHANNEL
SEDIMENT PROFILE
LINE SC06, FILES 267/0-281/3

FILE NAME: SC06H.DWG		
SCALE: 1"=4500'	DATE: NOVEMBER 7, 1995	PLATE 18

2

Appendix A
Delaware Main Channel Sediment Data

This appendix presents the physical sample data used during analysis of the geoacoustic data from the Delaware Main Channel. The data include the drilling logs and sediment gradation analysis where available. Table A1 lists all cores and their respective locations and dates retrieved. The core data are ordered in this appendix according to Table A1.

Table A1
Geoacoustic Study Core Locations

Core Name	Location			Date Collected
	Easting	Northing	Station	
DRV-1	724698	685339	50+266 / 336′ S of CL	7/25/91
DRV-2	711610	679945	65+000 / 854′ N of CL	7/25/91
DRV-3	691593	673346	86+680 / 40′ N of CL	7/26/91
DRV-4	668788	666020	111+830 / ON CL	7/26/91
DRV-5	663348	662042	118+557 / ON CL	7/27/91
DRV-6	657422	658240	125+623 / ON CL	7/19/91
DRV-7	646335	651122	138+797 / ON CL	7/27/91
DRV-8	639336	642260	150+210 / 359′ E of CL	7/27/91
DRV-9	632570	632025	162+638 / 120′ W of CL	7/19/91
DRV-10	629870	622669	172+363 / ON CL	7/28/91
DRV-11	619694	602545	195+448 / ON CL	7/28/91
DRV-12	618719	571387	232+018 / ON CL	7/28/91
DRV-13	615096	535014	265+712 / 86′ E of CL	7/19/91
DRV-14	652333	490616	326+356 / 666′ E of CL	7/29/91
DRV-15	668932	470366	355+000 / 287′ W of CL	7/29/91
DRV-16	679775	455794	373+062 / 1959′ W of CL	7/19/91
DRV-17	690876	443441	390+000 / 233′ W of CL	7/19/91
DRV-18	705861	428534	411+020 / 6200′ E of CL	7/18/91
DRV-19	705882	417615	418+792 / 527′ E of CL	7/18/91
DRV-20	712588	407641	426+679 / 190′ W of CL	7/18/91
DRV-21	717559	401405	437+692 / 189′ W of CL	7/18/91
DRV-22	722198	394780	445+900 / 100′ W of CL	7/18/91
DRV-23	726670	383605	457+500 / 115′ W of CL	7/17/91
DRV-24	730608	374423	467+011 / 128′ W of CL	7/17/91
DRV-25	734713	365347	476+524 / 142′ W of CL	7/17/91
DRV-26	742668	346964	500+000 / 309′ E of CL	7/16/91
DRV-27	746062	337592	509+532 / 188′ W of CL	6/14/91
DRV-28	752679	329679	520+000 / 2700′ E of CL	7/15/91
DRV-29	756852	314942	535+000 / 760′ E of CL	6/14/91
463	N/A	N/A	243+640 / 790′ W of CL	1/16/63

(Continued)

Table A1 (Concluded)

Core Name	Location			Date Collected
	Easting	Northing	Station	
461	N/A	N/A	241+680 / 640' W of CL	1/22/63
459	N/A	N/A	239+700 / 700' W of CL	1/17/63
DSP-1	N/A	N/A	233+680 / 480' W of CL	3/22/65
DSP-2	N/A	N/A	231+900 / 530' W of CL	3/22/65
DSP-3	N/A	N/A	229+840 / 460' W of CL	3/22/65
DSP-4	N/A	N/A	228+960 / 520' W of CL	3/23/65
DSP-5	N/A	N/A	219+800 / 610' W of CL	3-23-65
DFP-44	N/A	N/A	219+000 / 200' W of CL	12/13/86
DFP-45	N/A	N/A	219+000 / 200' E of CL	12/13/86
DFP-43	N/A	N/A	217+000 / 200' W of CL	12/13/86
DFP-36	N/A	N/A	212+000 / 400' E of CL	12/13/86
DFP-35	N/A	N/A	210+500 / 400' E of CL	12/11/86
DFP-32	N/A	N/A	209+000 / 450' E of CL	12/10/86
DFP-31	N/A	N/A	205+000 / 200' E of CL	12/9/86
DFP-26	N/A	N/A	200+000 / 200' E of CL	12/6/86
DSP-7	N/A	N/A	197+480 / 500' W of CL	3/24/65
DFP-25	N/A	N/A	195+000 / 200' E of CL	12/6/86
DFP-24	N/A	N/A	190+000 / 200' E of CL	12/6/86
DSP-9	N/A	N/A	172+030 / 270' W of CL	3/29/65
431	N/A	N/A	159+700 / 240' W of CL	1/17/62
435	N/A	N/A	151+920 / 455' E of CL	1/19/62
437	N/A	N/A	149+950 / 450' W of CL	1/19/62
436	N/A	N/A	150+000 / 450' E of CL	1/19/62
438	N/A	N/A	146+000 / 450' W of CL	1/22/62
DRP-12	N/A	N/A	130+930 / 165' E of CL	6/9/65
282	N/A	N/A	119+420 / ON CL	9/6/61
DSP-16	N/A	N/A	76+210 / 500' W of CL	4/1/65
DSP-17	N/A	N/A	68+880 / 290' E of CL	4/2/65
DSP-19	N/A	N/A	50+230 / 310' W of CL	4/2/65
DSP-20	N/A	N/A	41+890 / 290' E of CL	4/3/65

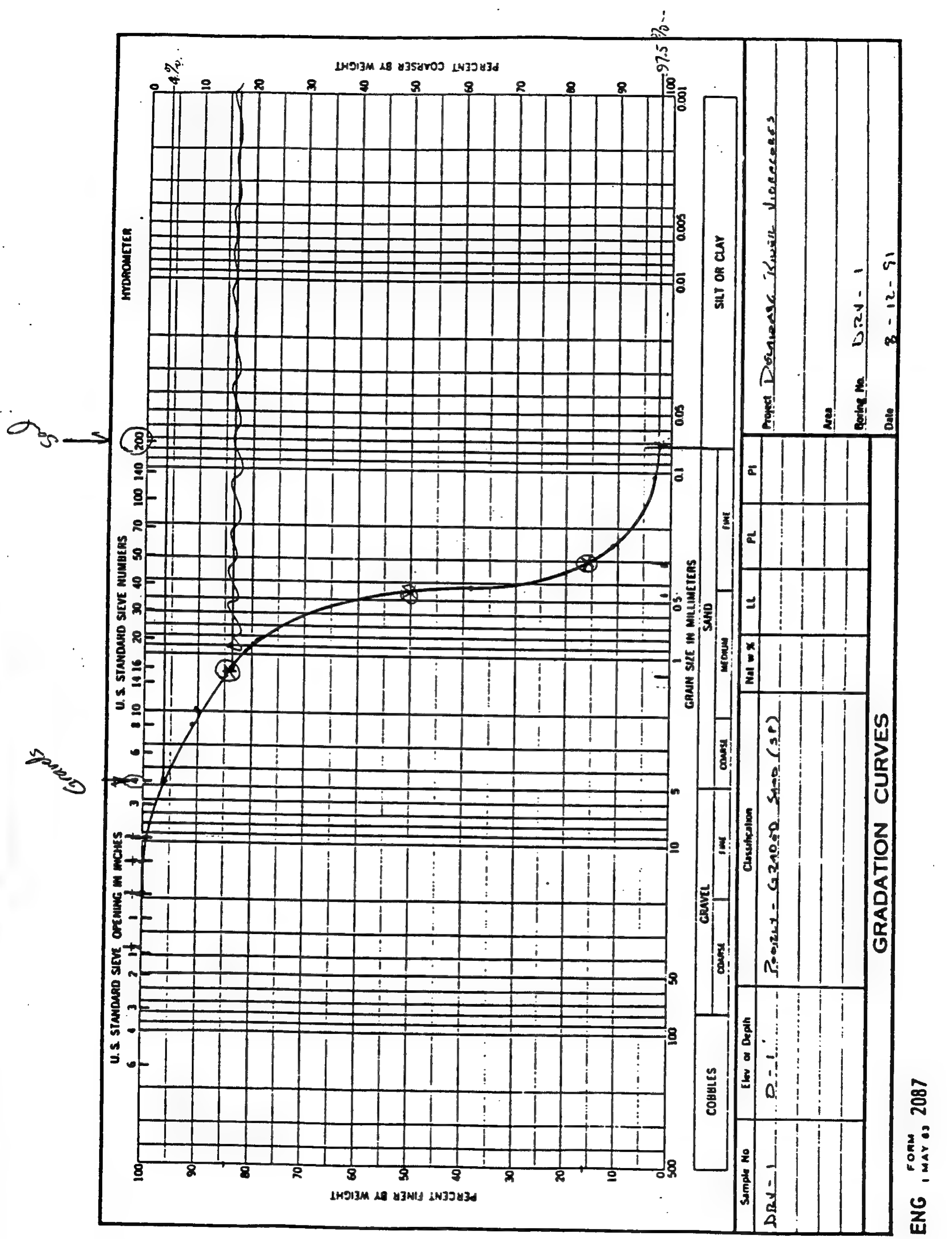
Hole No. DRV-1

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

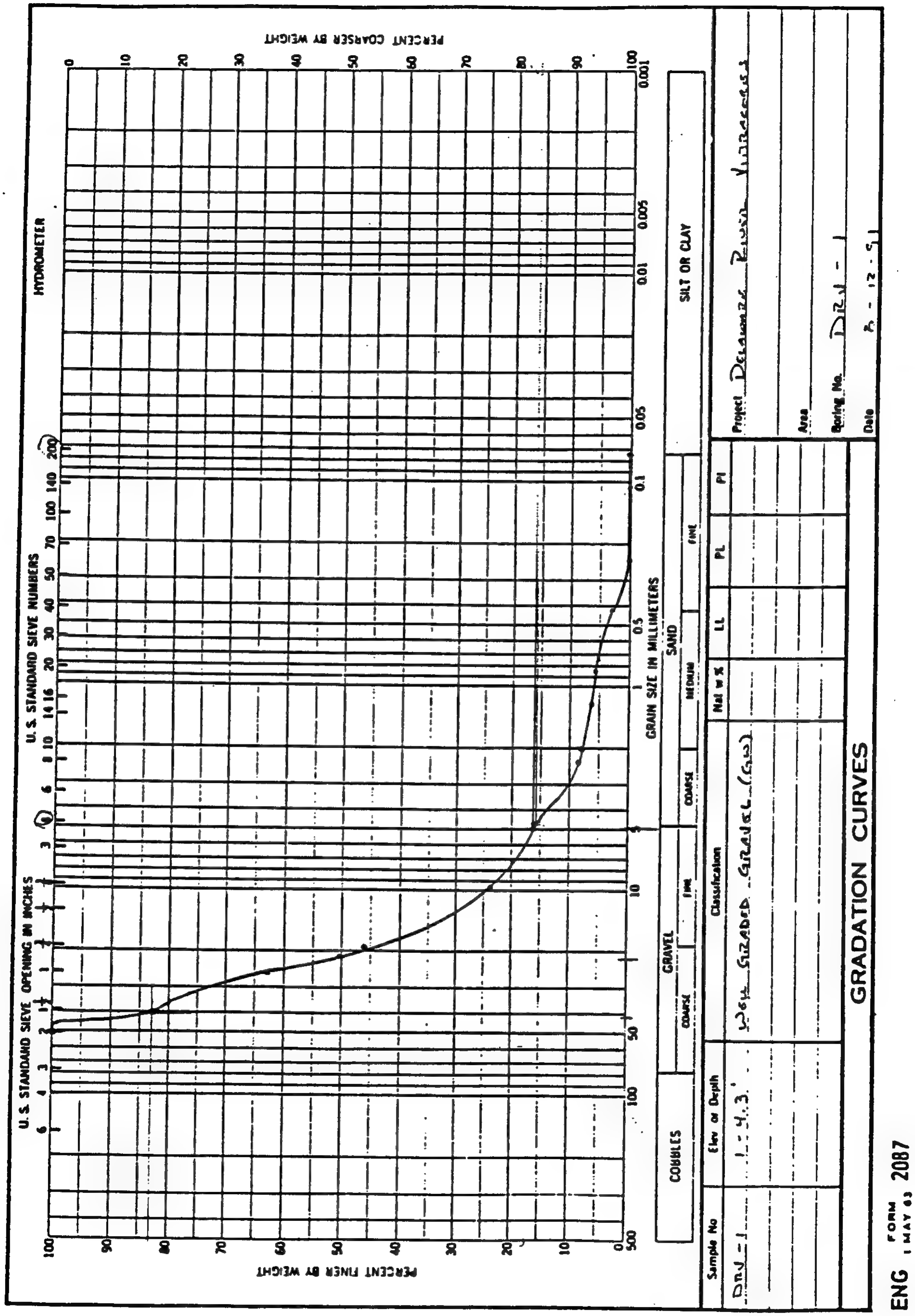
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 52' 52.69" 75° 10' 22.28"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) TBM
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/25/91 : COMPLETED 07/25/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -45.7 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 18 ft.
	19. SIGNATURE OF INSPECTOR

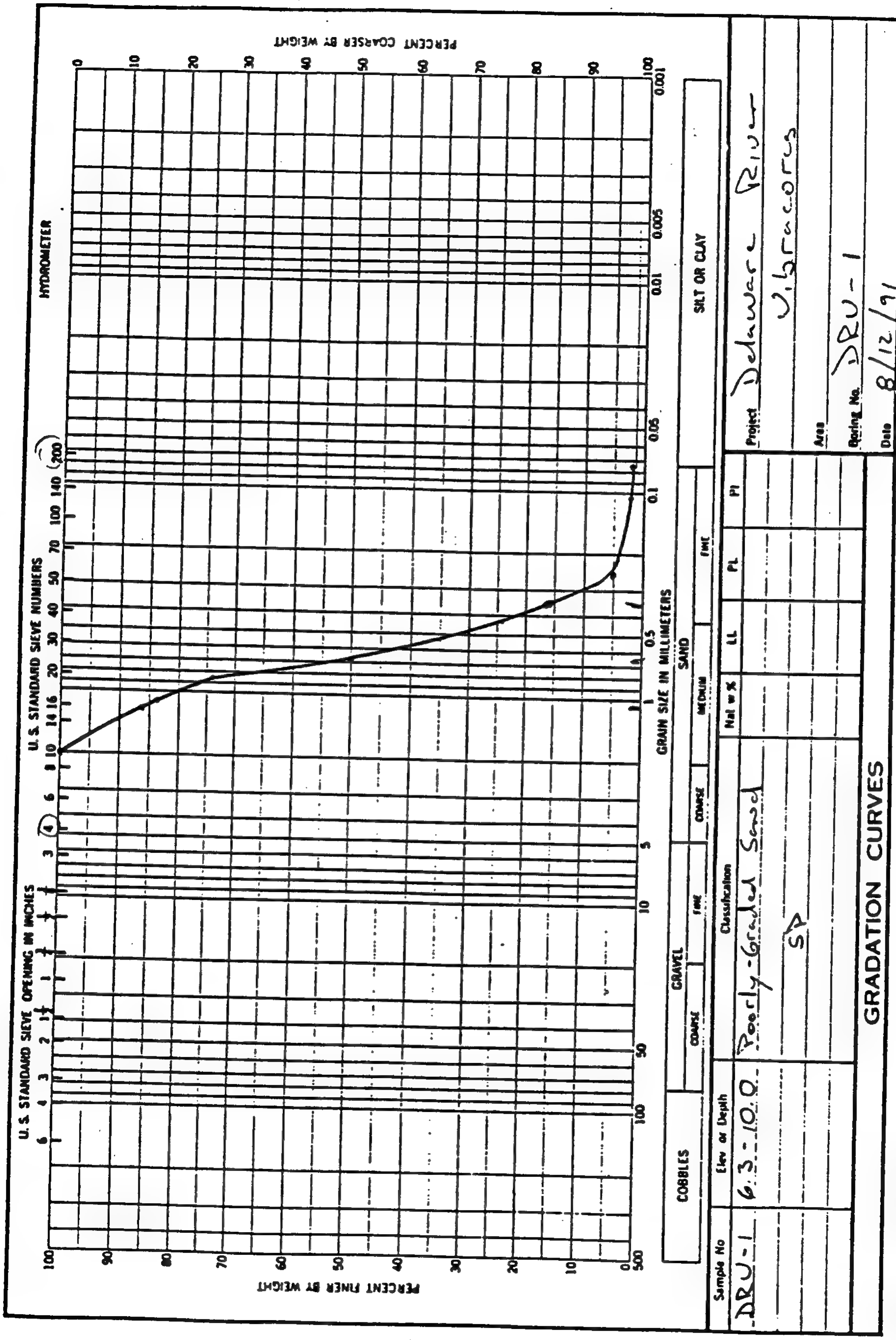
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Grey medium to fine sand with scattered fine gravel			One retry Sample 0 - 1 ft.
	1		Grey sandy coarse to fine gravel. Predominately quartz with medium sand			Sample 1 - 4.3 ft.
	4.3		Grey medium to fine sand ....scattered fine gravel			~~[illegible]~~
	6.3		Grey gravelly medium to fine sand with medium to fine gravel			Sample 6.3 - 10 ft.
	10		Less gravel Grey medium to fine sand			Sample 10 - 14.7 ft.
	13.7		Brown medium to fine sand			
	14.7		Grey medium to fine silty sand with brown medium to fine sand lenses			Sample 14.7 - 18 ft.
	18					Bottom of recovery

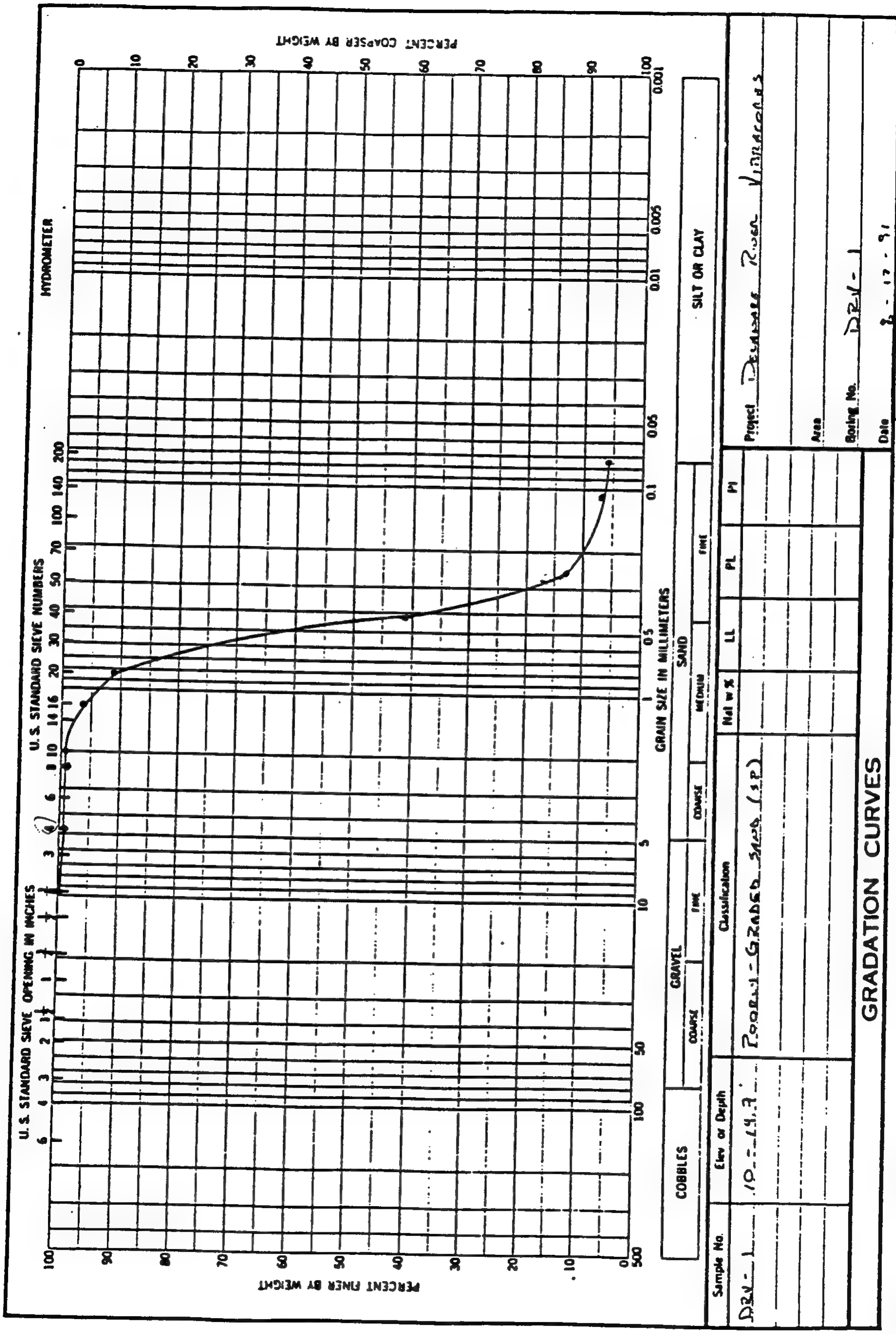
PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-1

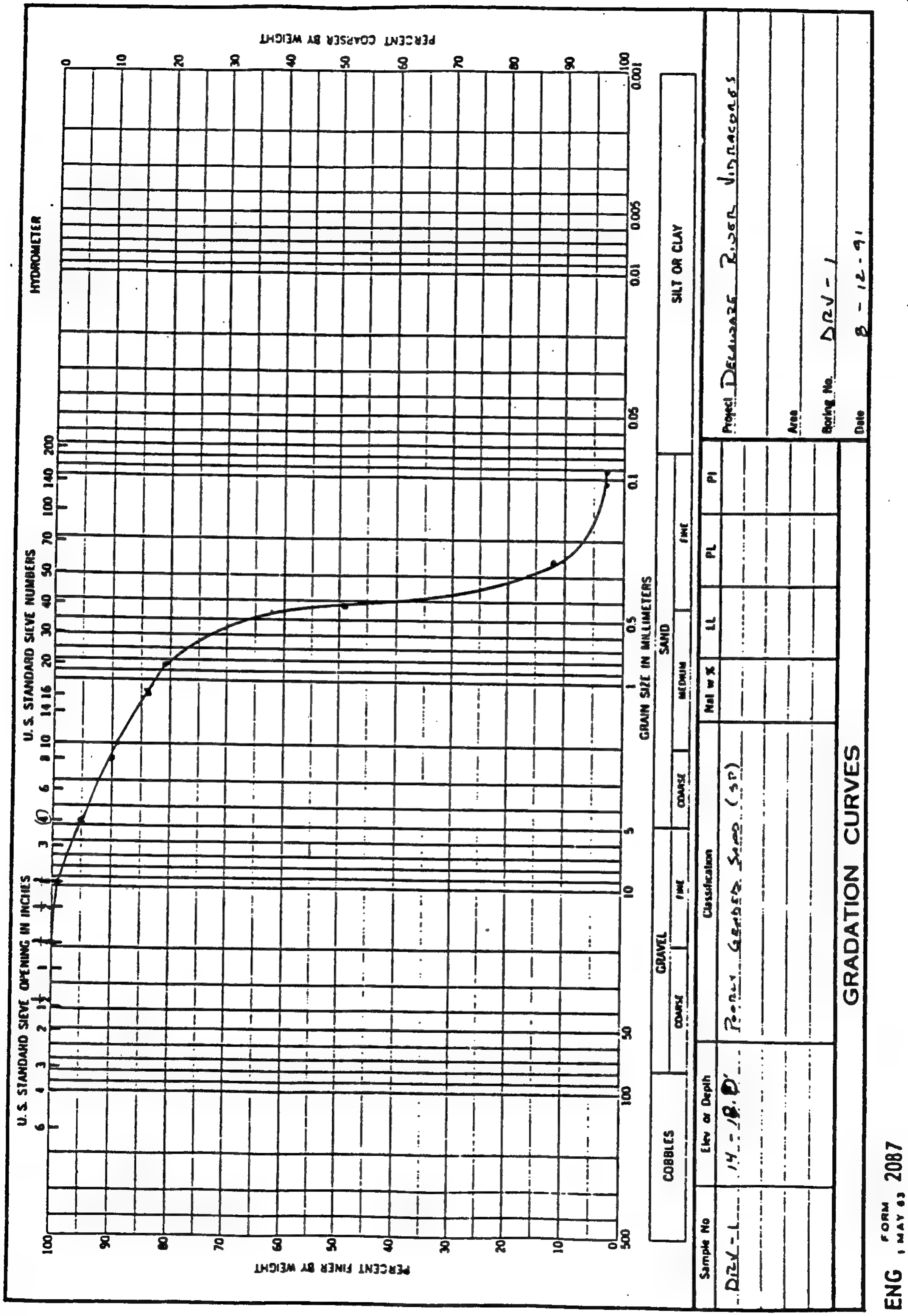


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Gravel
Sand
4.%
97.5%
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-1
0-1'
Poorly-Graded Sand (SP)
Project
Area
Boring No. DRV-1
Date 8-12-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRJ-1
Elev or Depth
1-4.3'
Classification
Well Graded Gravel (GW)
Nat w %
LL
PL
PI
Project
Area
Boring No.
DRJ-1
Date
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-1
Elev or Depth
6.3-10.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-1
Date 8/12/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRV-1
Elev or Depth 10-19.7'
Classification Poorly-Graded Sand (SP)
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-1
Date 8-17-91
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-1
Elev or Depth
14.-18.0'
Classification
Poorly Graded Sand (SP)
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-1
Date 8-12-91
ENG FORM 1 MAY 63 2087

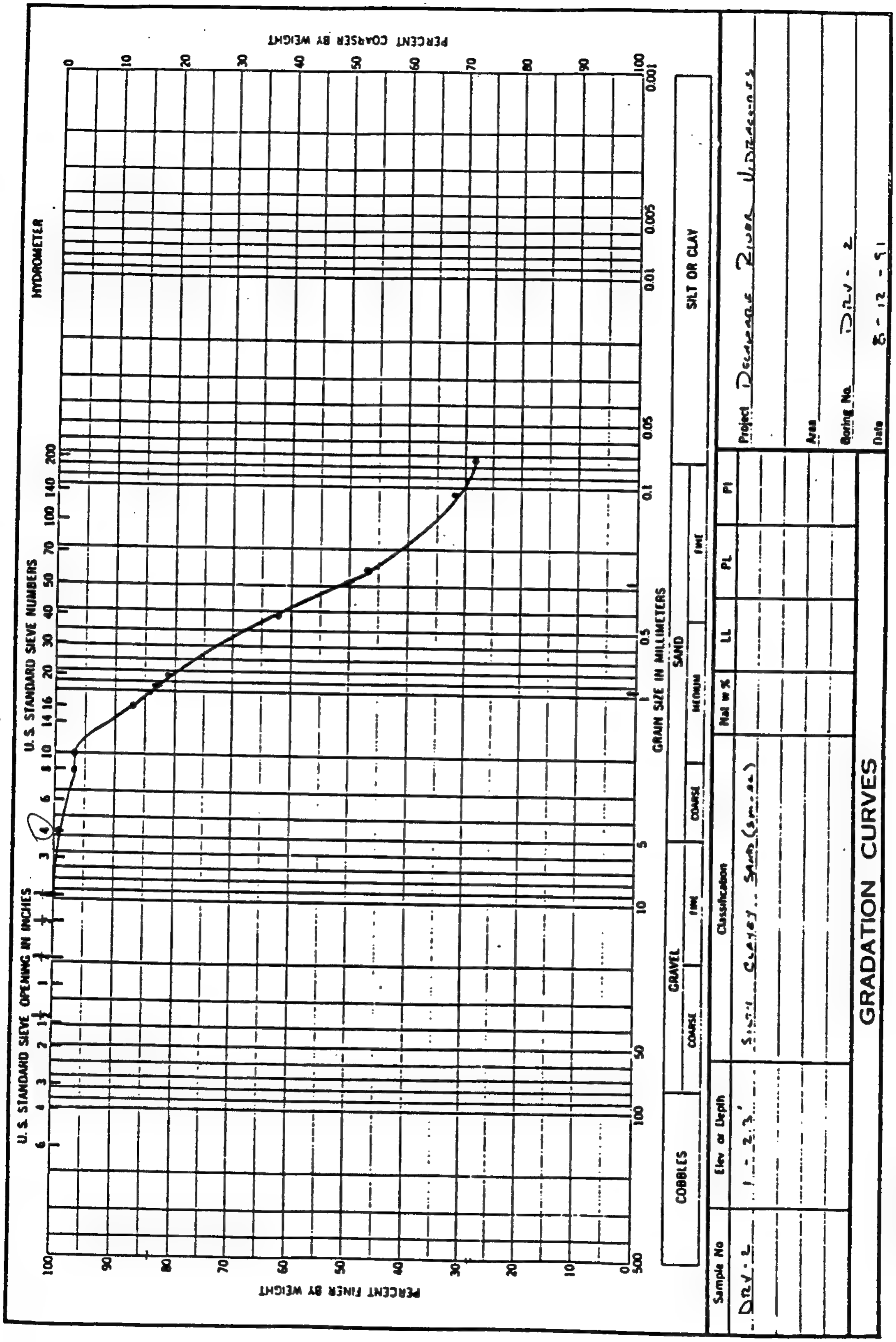
Hole No. DRV-2

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

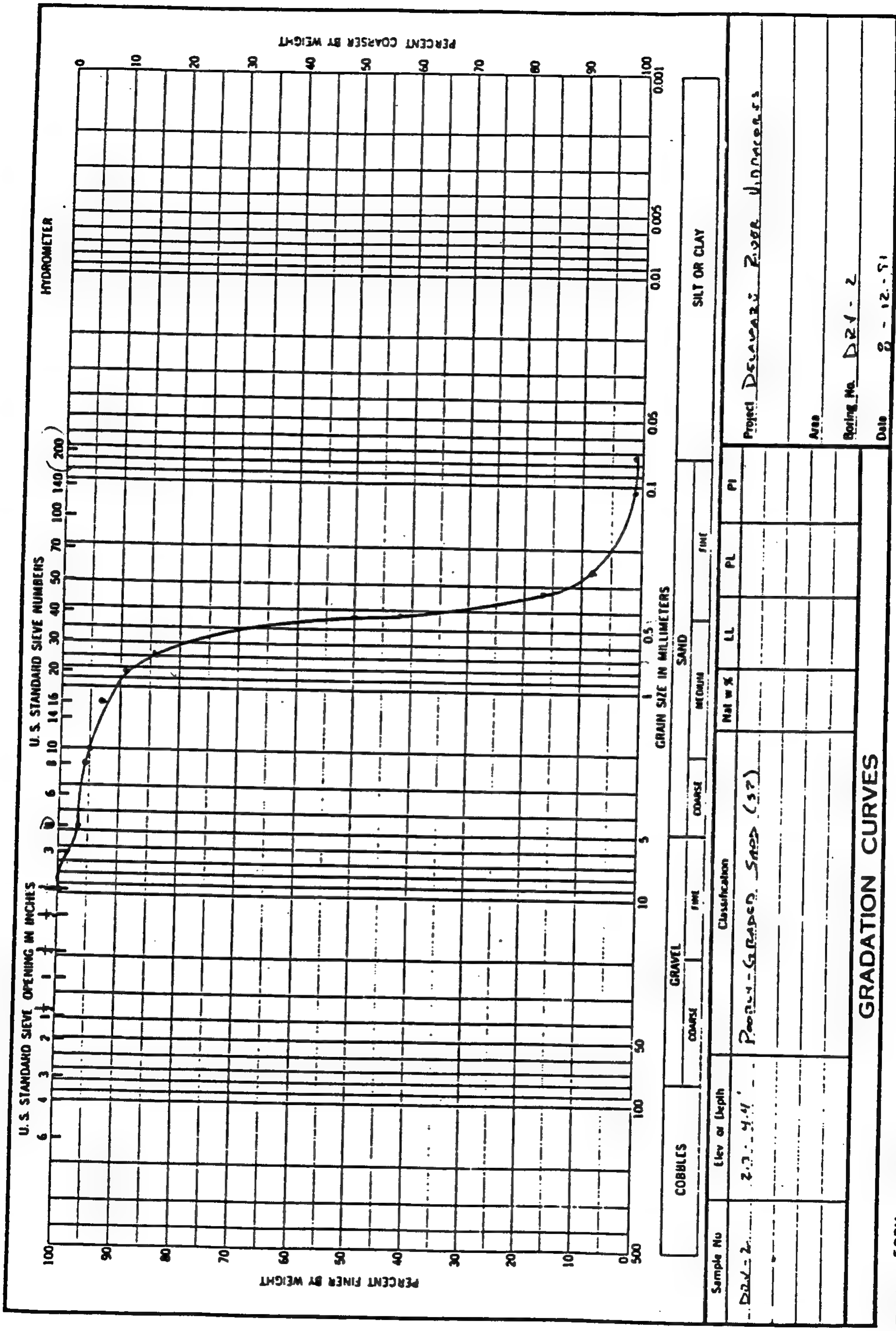
1. PROJECT: Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT: Vibracore
2. LOCATION (Coordinates or Station): 39° 51' 59.70" 75° 13' 10.29"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL: NA
4. HOLE NO. (As shown on drawing title and file number): DRV-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: NA: DISTURBED : UNDISTURBED
5. NAME OF DRILLER: Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES: NA
6. DIRECTION OF HOLE: VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: NA
7. THICKNESS OF OVERBURDEN: NA	16. DATE HOLE: STARTED 07/25/91 : COMPLETED 07/25/91
8. DEPTH DRILLED INTO ROCK: NA	17. ELEVATION TOP OF HOLE: -47.9 ft. NGVD
9. TOTAL DEPTH OF HOLE: 20 ft. (Assumed)	18. TOTAL CORE RECOVERY FOR BORING: 16 ft.
	19. SIGNATURE OF INSPECTOR

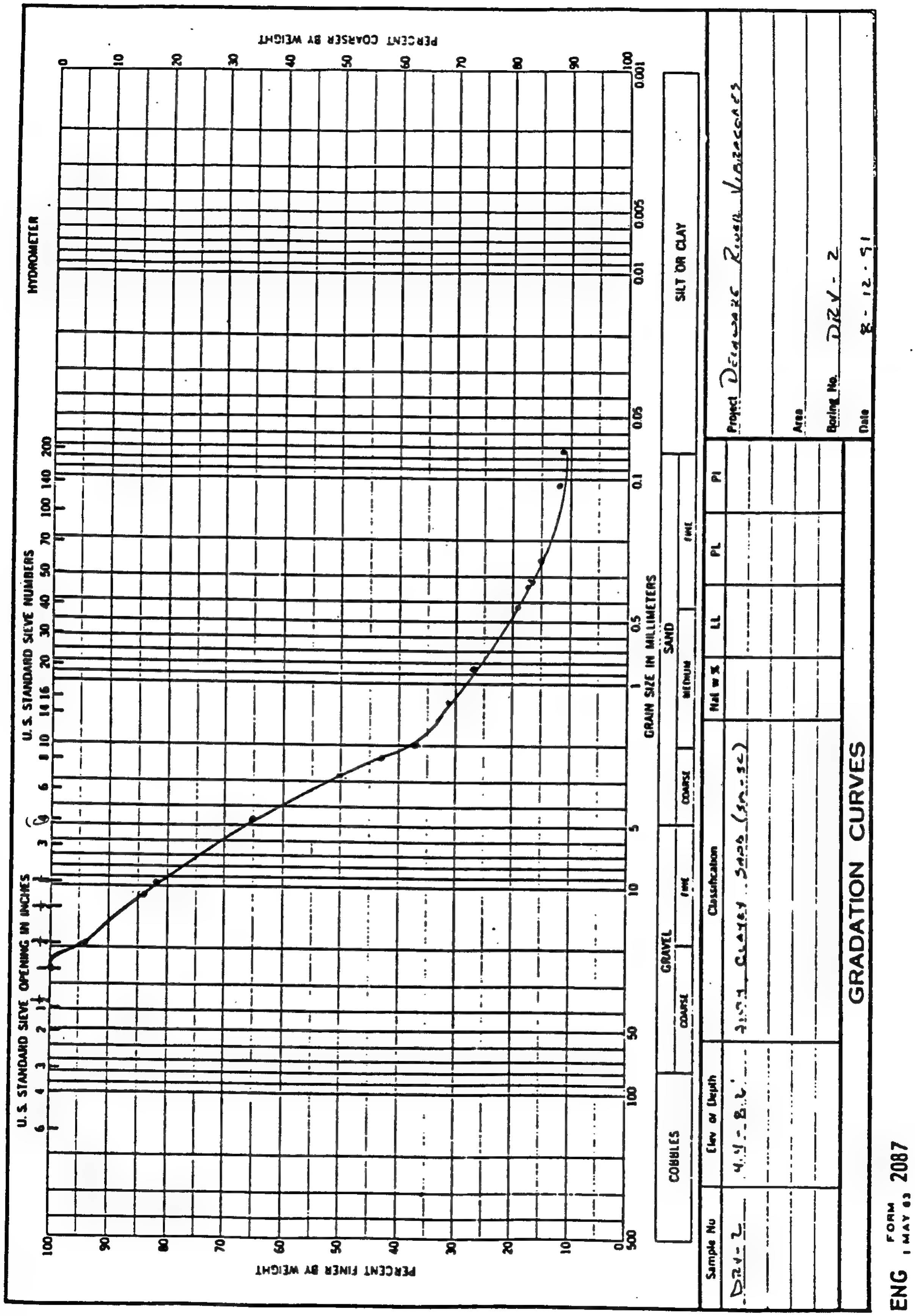
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–.4		Grey silt			
	.4–.9		Brown medium to fine sand			
	.9–2.3		Grey silt, sandy layers >.01 inch thick			Sample 1 - 2.3 ft. Sample includes sandy layers
	2.3–4.4		Grey fine to medium sand			Sample 2.3 - 4.4 ft.
	4.4–5.3		Black sandy gravelly silt			
	5.3–8.2		Grey clay with sandy gravel at 5 to 5.4, gravel layer at 6.6 to 6.8, 7.4 to 7.5			Sample 4.4 - 8.2 ft.
	8.2–8.8		Sandy gravel, coarse to fine gravel			
	8.8–12.4		Grey medium to fine sand, coarse fine scattered gravel finer gravel downward			Sample 8.8 to 10. 8 ft.
	12.4–16		Silty sand grading to silt with sandy layers, layer of sand at 15.4 to 15.5; clay to 16 ft.			Sample 12.4 - 16 ft. Sample of silt
	16					Bottom of recovery

PROJECT: Delaware River Comprehensive Study — HOLE NO. DRV-2

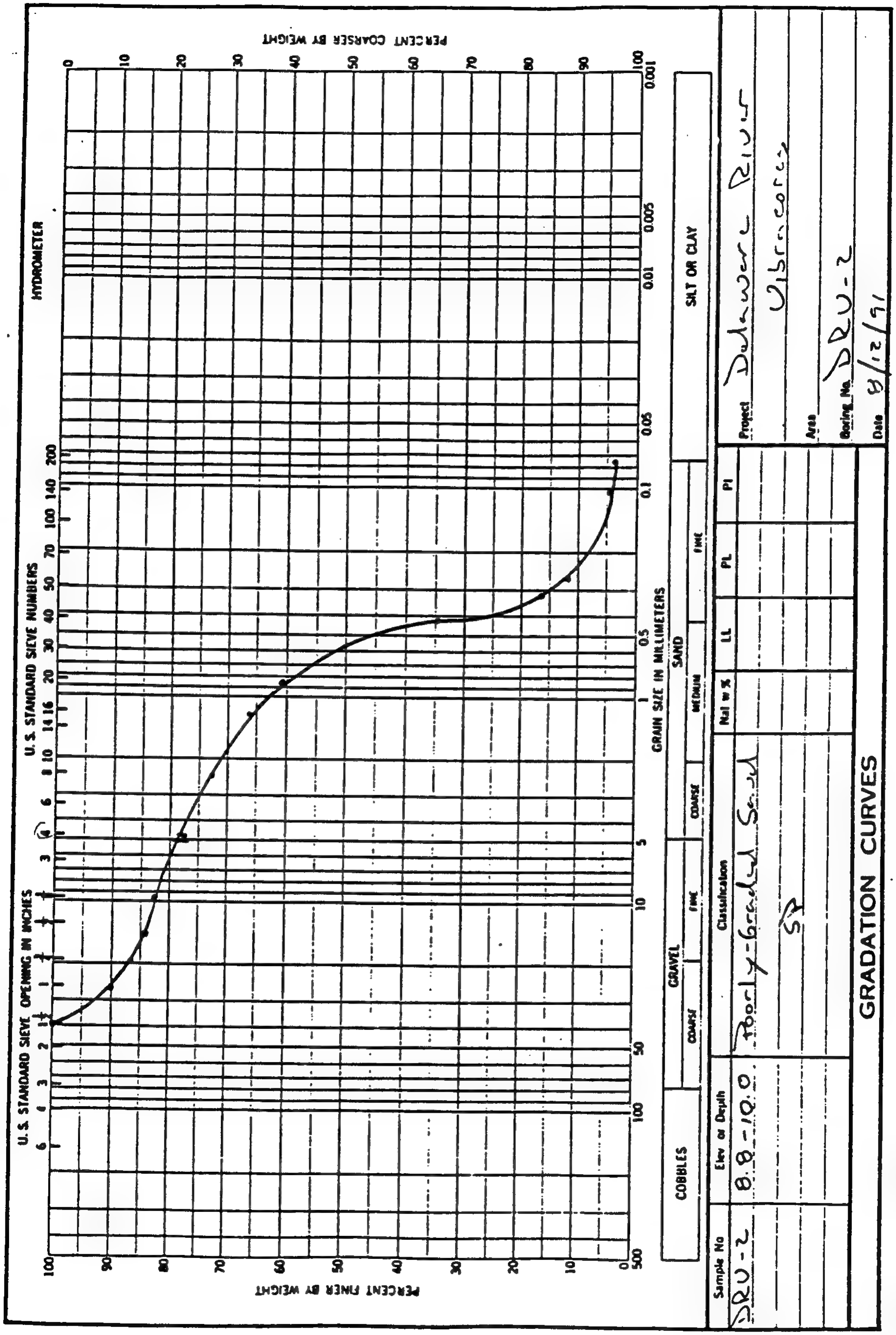


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

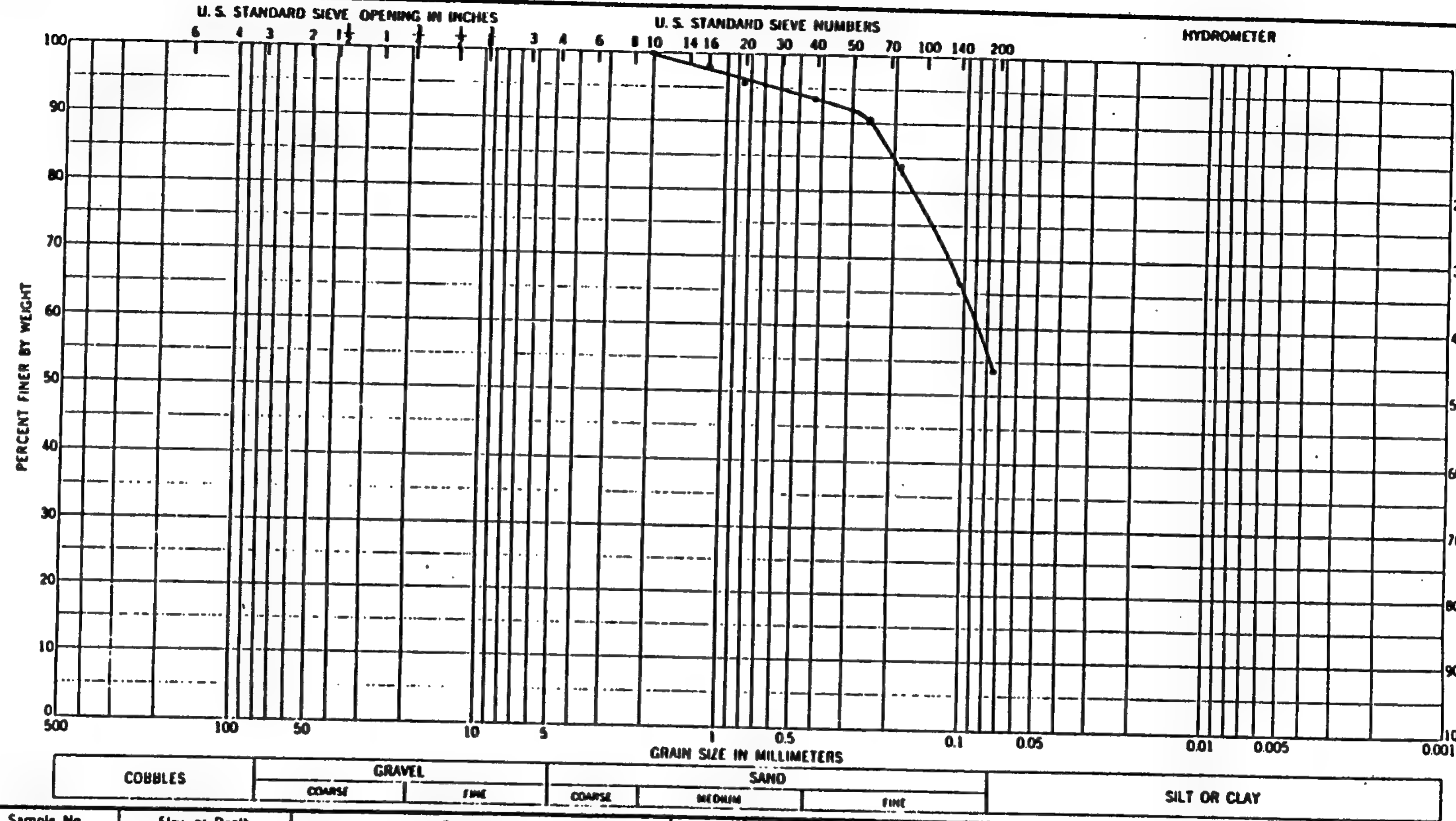

GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-2
Date 8-12-91
DRV-2
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-2
Elev or Depth
8.8-10.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-2
Date 8/12/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV - 2	12.4 - 16'	Silt		Non -	Plas	tic
		ML				

Project: Delaware River Vibracores

Area:

Boring No. DRV - 2

Date: 8 - 12 - 91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

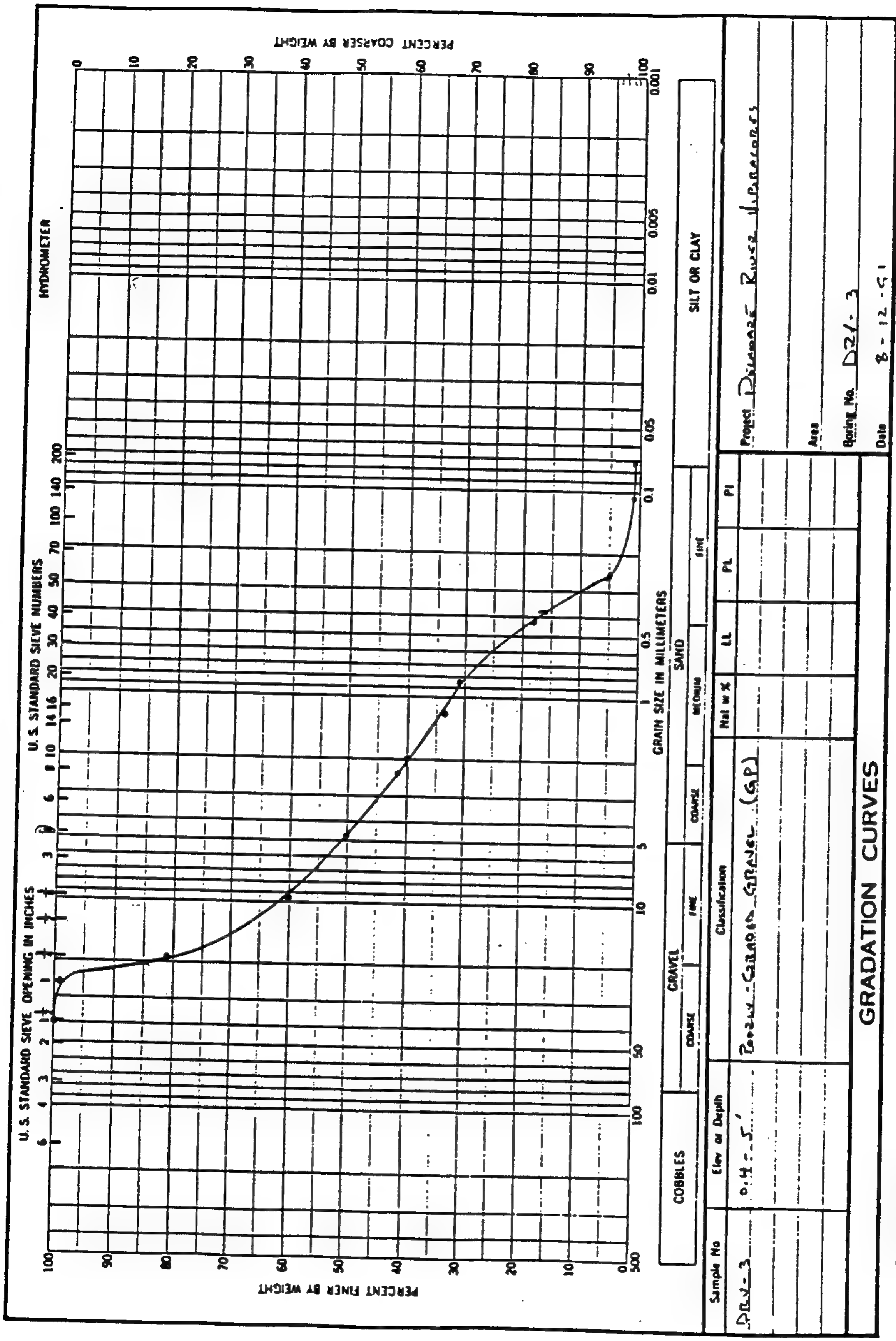
Hole No. DRV-3

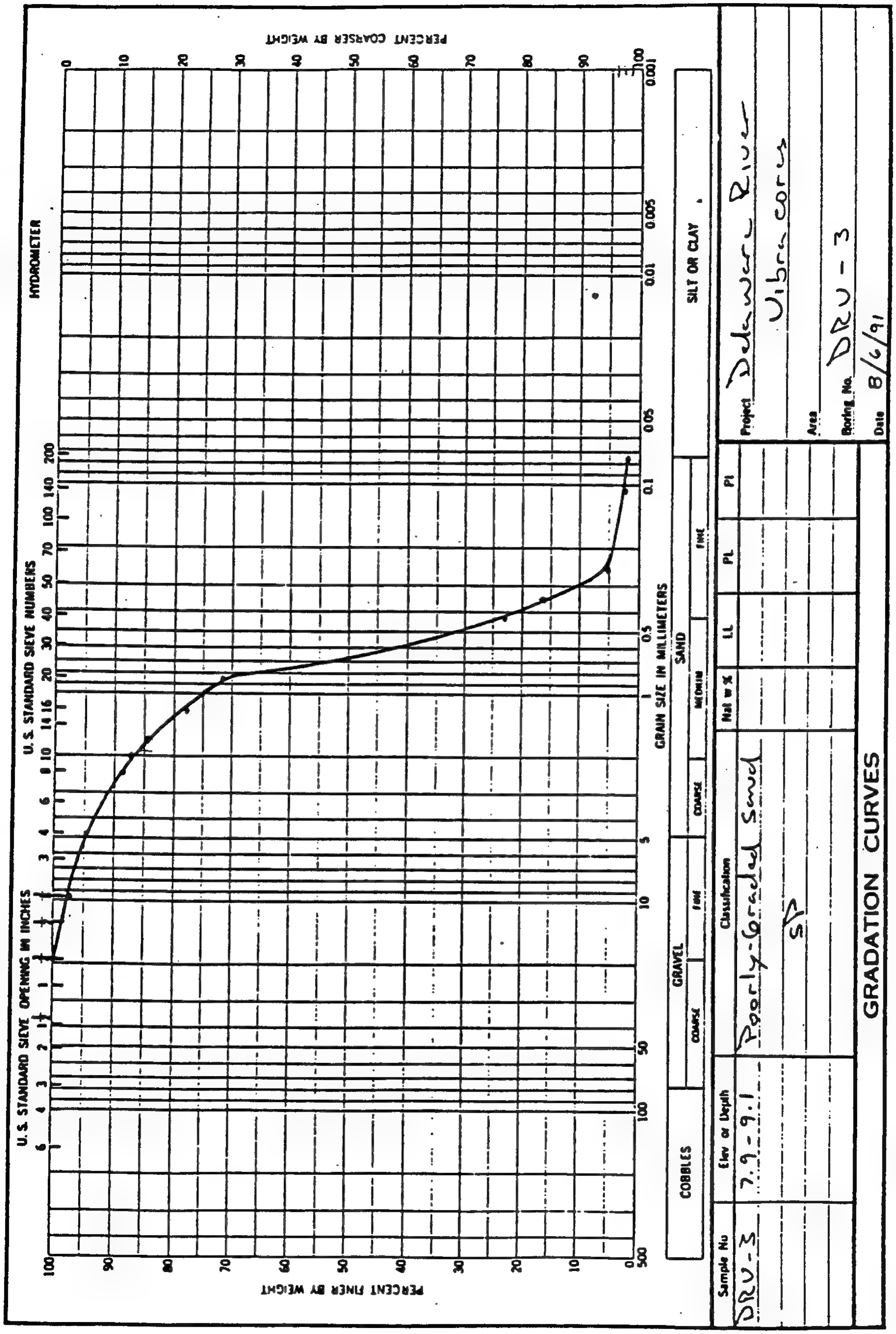
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

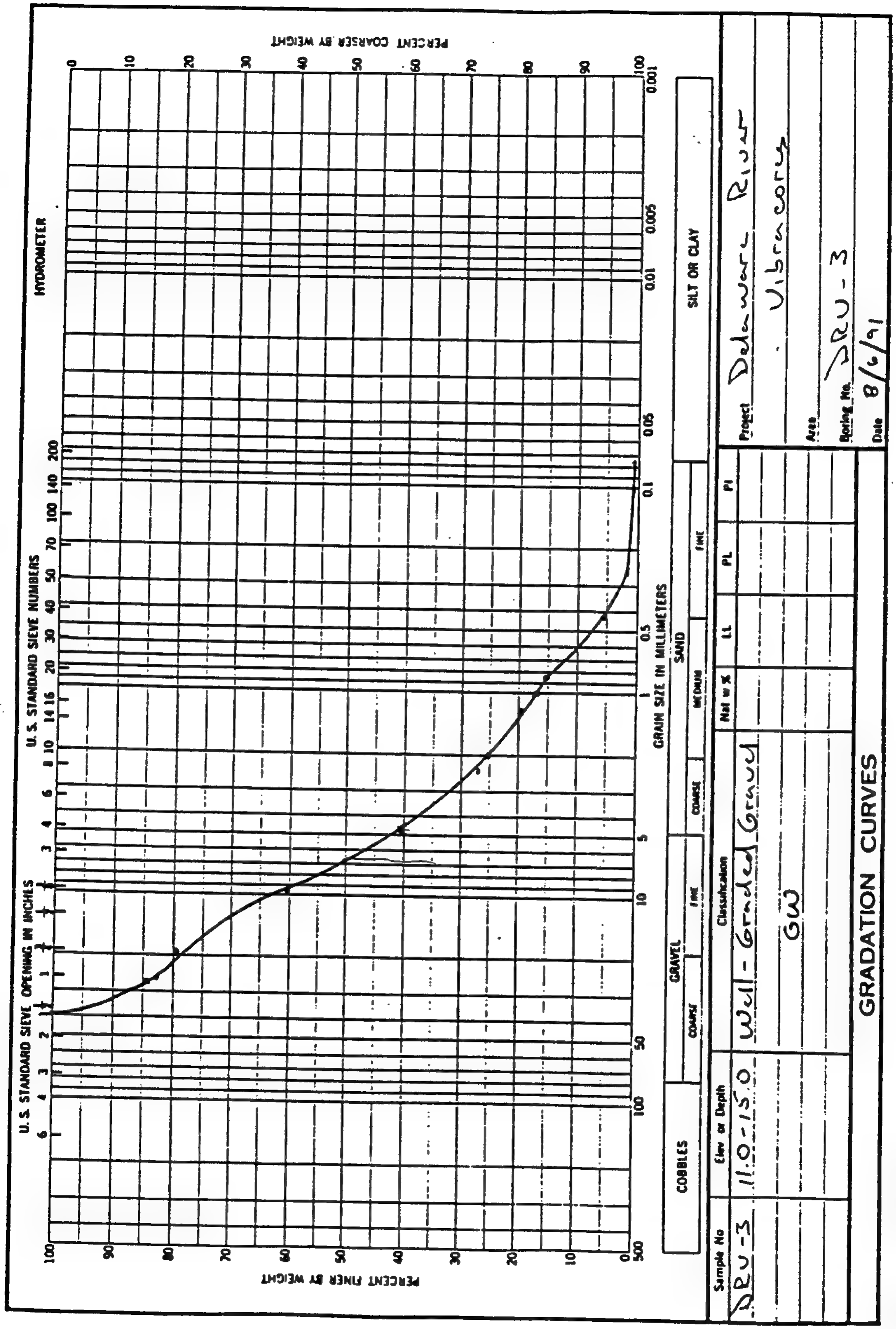
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 50' 54.85" 75° 17' 27.10"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-3	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
	15. ELEVATION GROUND WATER NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	16. DATE HOLE : STARTED 07/26/91 : COMPLETED 07/26/91
7. THICKNESS OF OVERBURDEN NA	17. ELEVATION TOP OF HOLE -47.2 ft. NGVD
8. DEPTH DRILLED INTO ROCK NA	18. TOTAL CORE RECOVERY FOR BORING 19.5 ft.
9. TOTAL DEPTH OF HOLE 19.5 ft.	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	.4		Black sandy med. to fine gravel	SP-		
	1		Brown sandy coarse to fine gravel with coarse to fine sand GP			
	2					12.5 ft., 11, 20 ft. - Penetration Sample .4 - 5 ft.
	7		Light brown coarse fine gravel, trace of sand GW			V
	7.9		Brown medium to fine sand SP			Sample 7.9 - 9.1 ft.
	9.1		Brown coarse to fine gravel with sand, some small cobbles GW			
	12					Sample 11 - 15 ft.
	15.8		Brown sandy coarse to fine gravel with coarse to fine sand SP			Sample 15.8 - 19.5 ft.
	19.5					19.5 ft. bottom of recovery

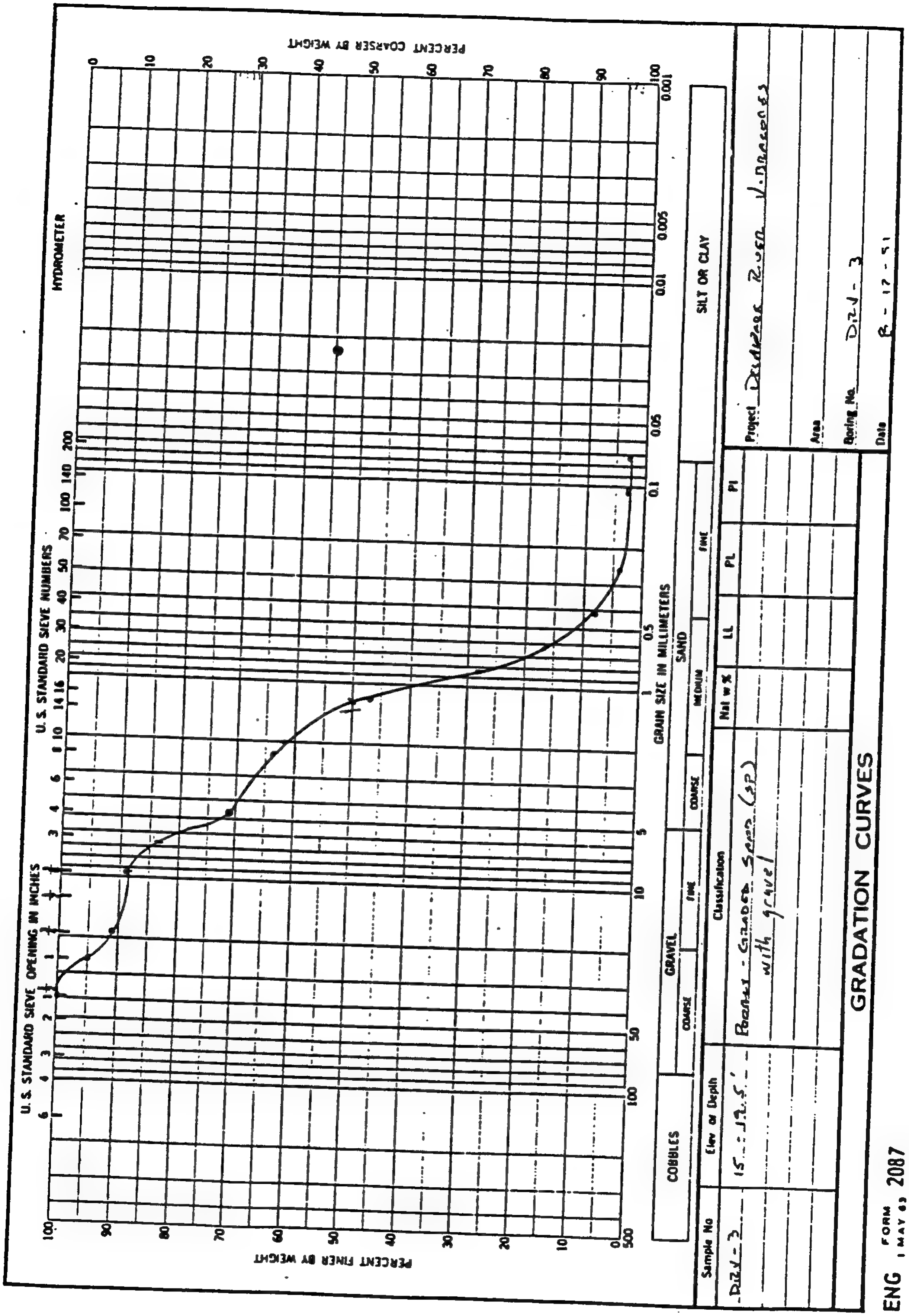
PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-3


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-3
Elev or Depth
7.9-9.1
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project
Delaware River
Vibracores
Area
Boring No.
DRV-3
Date
8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-3
Elev or Depth
11.0-15.0
Classification
Well-Graded Gravel
GW
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-3
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Hole No. DRV-4

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT
Delaware River Comprehensive Study

2. LOCATION (Coordinates or Station)
39° 49' 42.66" 75° 22' 19.54"

3. DRILLING AGENCY
Buchart-Horn, Inc.

4. HOLE NO. (As shown on drawing title and file number) DRV-4

5. NAME OF DRILLER Ocean Survey, Inc.

6. DIRECTION OF HOLE
VERTICAL INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN NA

8. DEPTH DRILLED INTO ROCK NA

9. TOTAL DEPTH OF HOLE 8 ft.

10. SIZE AND TYPE OF BIT Vibracore

11. DATUM FOR ELEVATION SHOWN (TBM or MSL)

12. MANUFACTURER'S DESIGNATION OF DRILL
NA

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED

14. TOTAL NUMBER CORE BOXES NA

15. ELEVATION GROUND WATER NA

16. DATE HOLE : STARTED 07/26/91 : COMPLETED 07/26/91

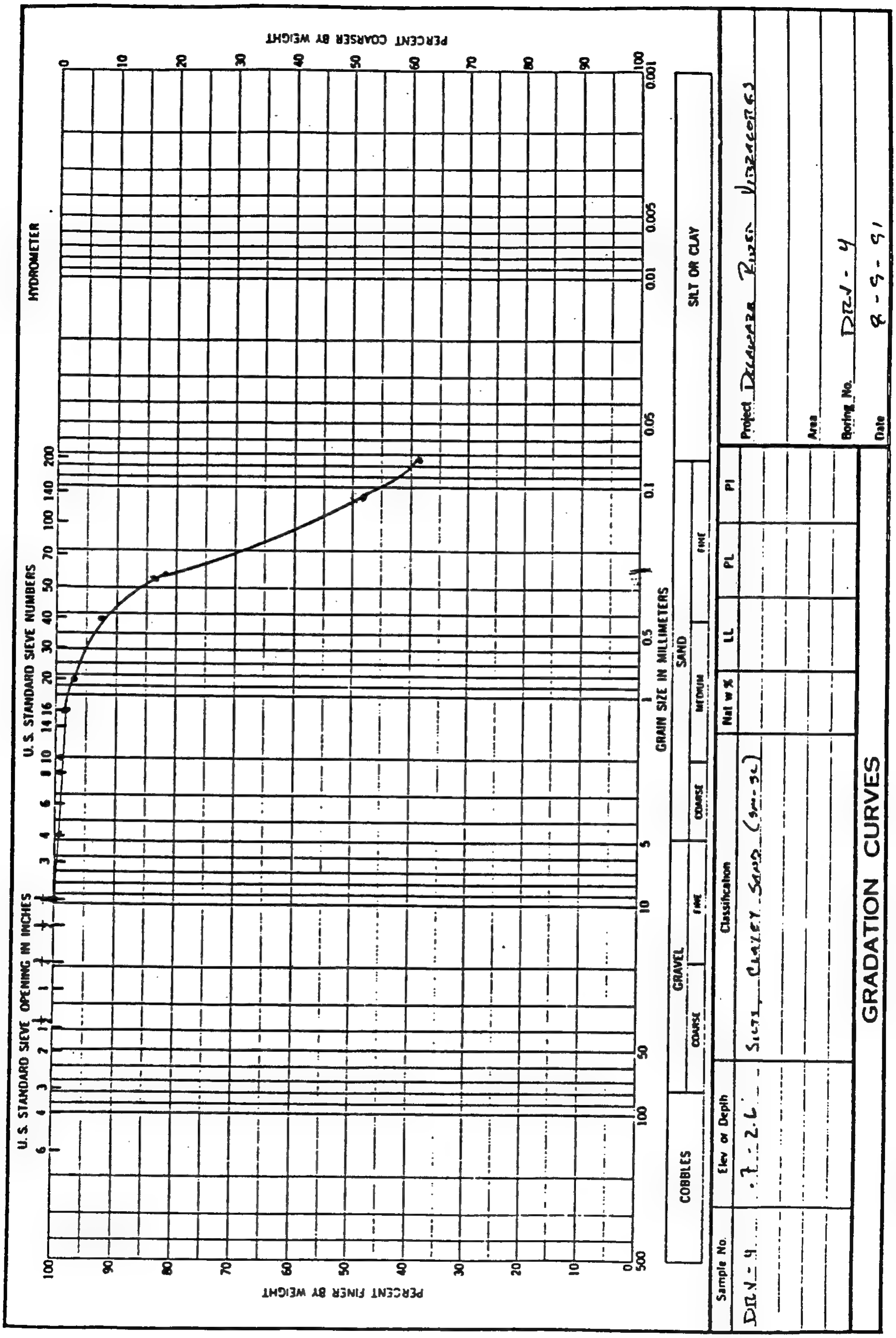
17. ELEVATION TOP OF HOLE
-45.9 ft. NGVD

18. TOTAL CORE RECOVERY FOR BORING 6.75 ft.

19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–.7		Cobbles with coarse to fine sandy gravel GP			8 ft. penetration
	.7–2.6		Brown silty fine sand SM-SC			Sample .7 to 2.6 ft.
	2.6–4.5		Small cobbles with coarse to fine sandy gravel GP			
	4.5–6.75		Saprolite of Chlorite-Albite micaceous shist Bedrock			
	6.75					Bottom of recovery

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-4



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 2087

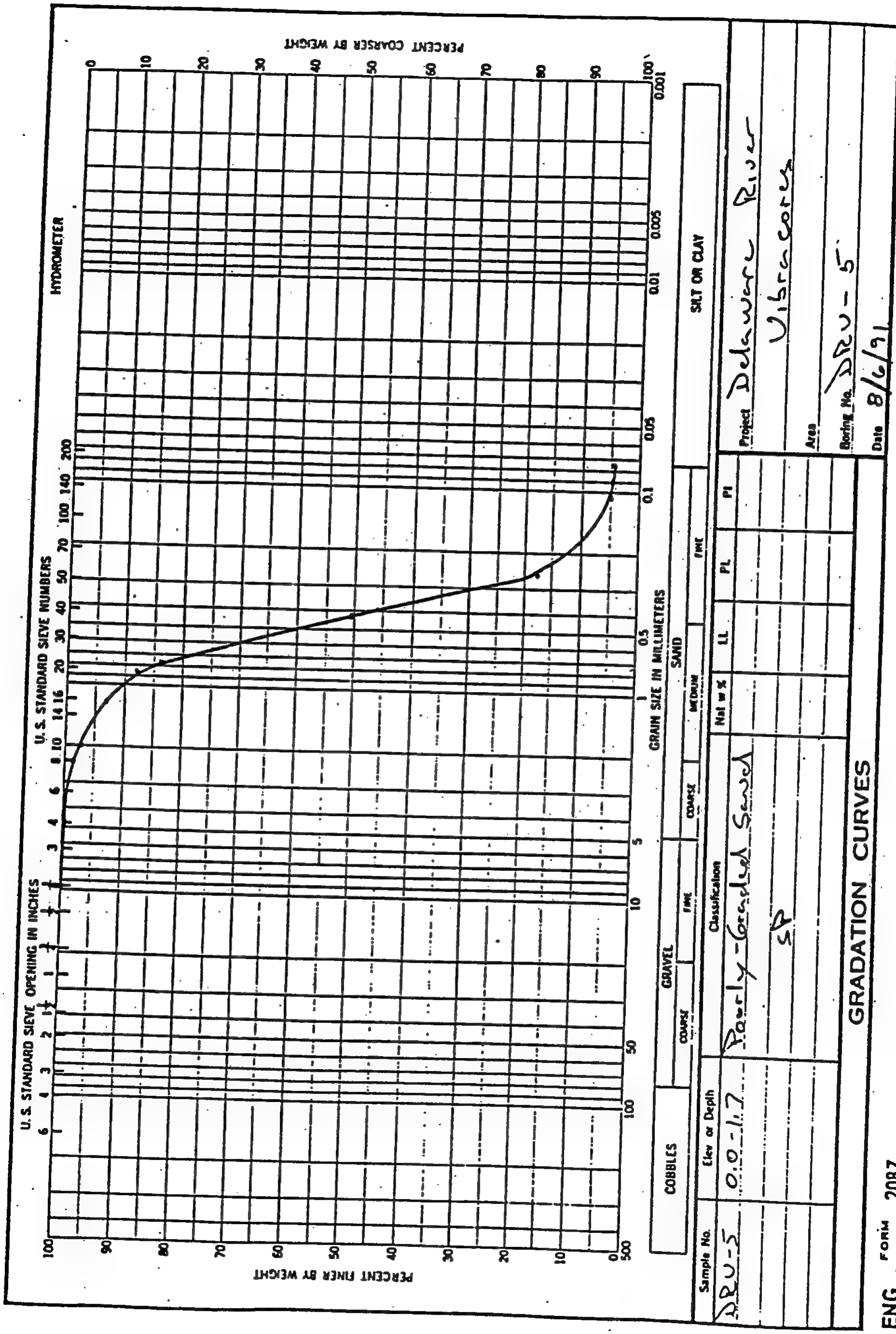
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 49.39' 3.37" 75° 23' 29.28"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-5	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
	14. TOTAL NUMBER CORE BOXES NA
5. NAME OF DRILLER Ocean Survey, Inc.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE : STARTED 07/27/91 : COMPLETED 07/27/91
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	17. ELEVATION TOP OF HOLE -49.0 ft. NGVD
7. THICKNESS OF OVERBURDEN NA	18. TOTAL CORE RECOVERY FOR BORING 4.3 ft.
8. DEPTH DRILLED INTO ROCK NA	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE 40 ft.	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–1.7		Medium to fine dark grey sand SP			Sample 0.0 - 1.7 ft.
	1.7–2.1		Grey silt SM			
	2.1–3.8		Medium to fine dark grey sand becoming coarser with depth SP			
	3.8–4.3		Cobbles GW			Bottom of recovery
			Gneiss Bed·r			

Depth scale: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

PROJECT Delaware River Comprehensive Study HOLE NO. DRV-5


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.: DRV-5
Elev or Depth: 0.0-1.7
Classification: Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project: Delaware River Vibracores
Area
Boring No. DRV-5
Date 8/6/91
ENG FORM 2087

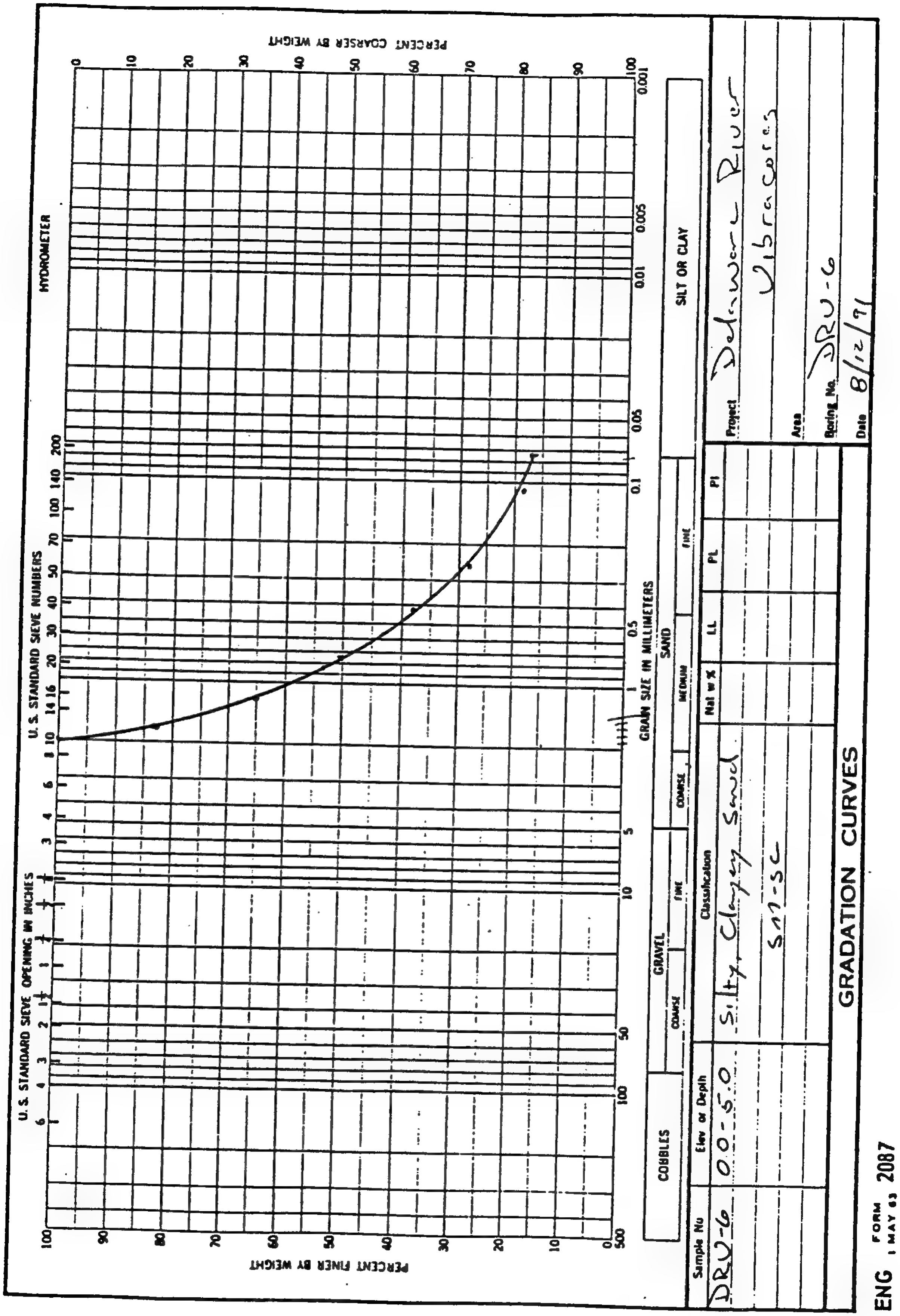
Hole No. DRV-6

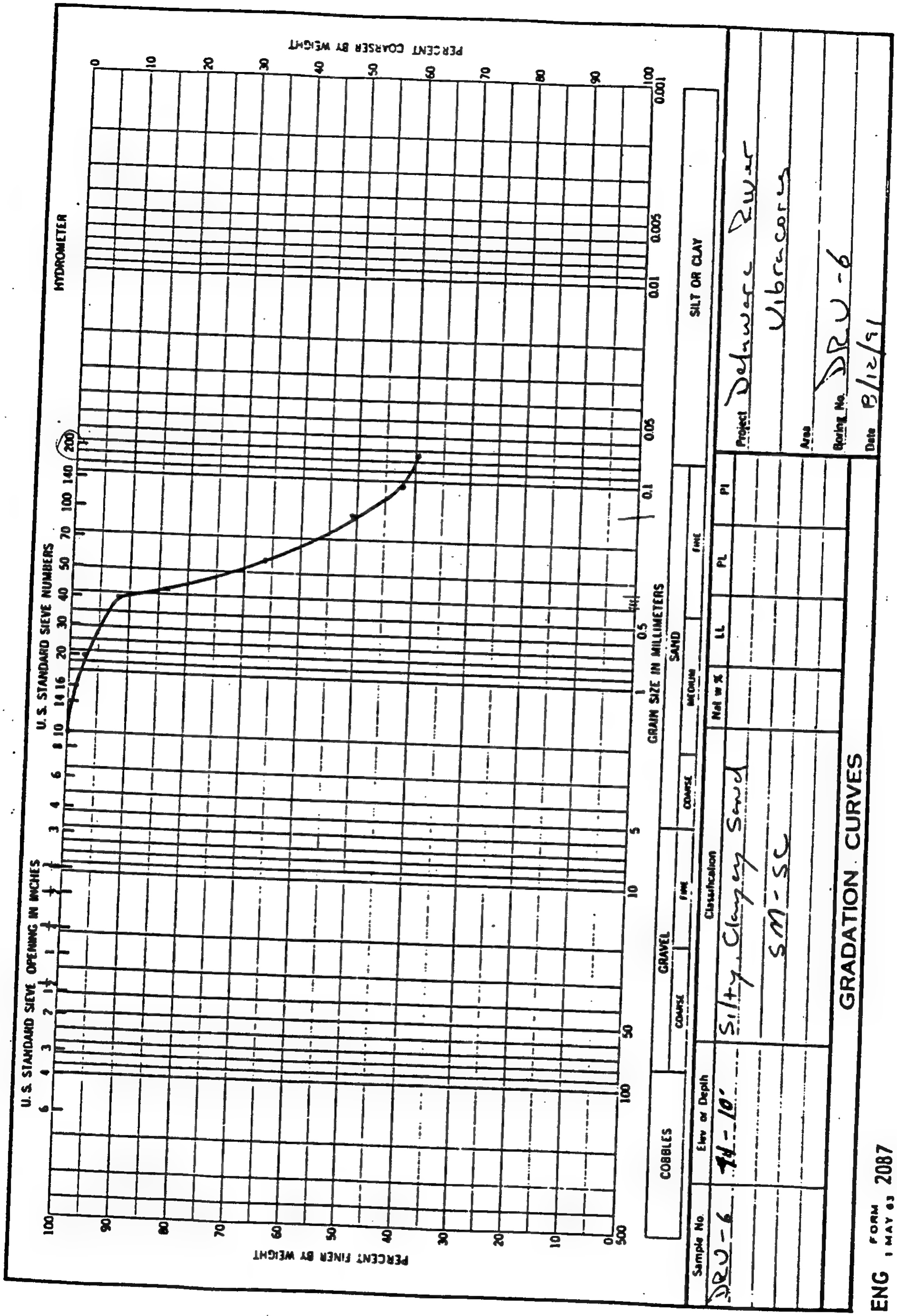
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

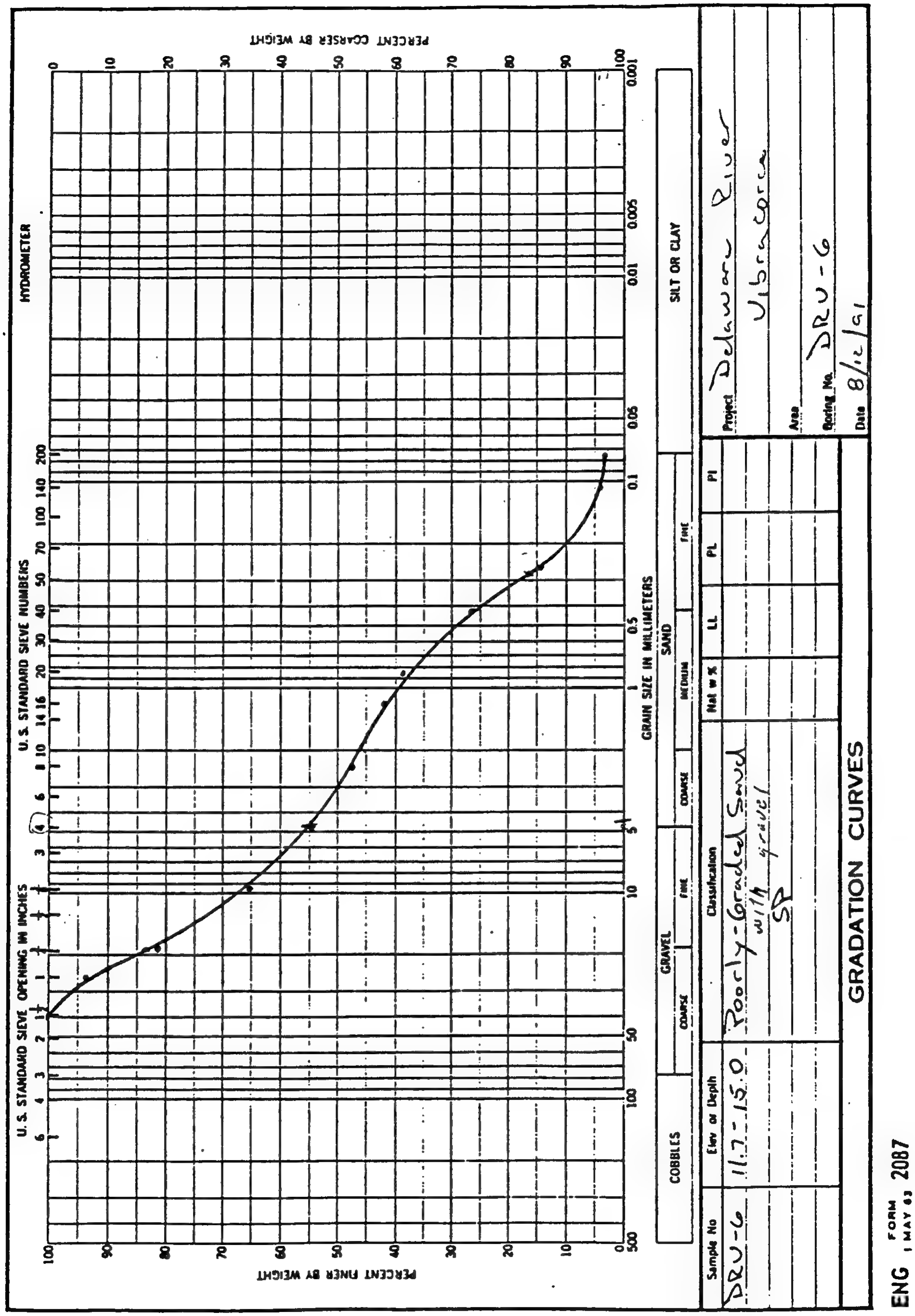
1. PROJECT: Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT: Vibracore
2. LOCATION (Coordinates or Station): 39° 48' 25.88" 75° 24' 45.22"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL: NA
4. HOLE NO. (As shown on drawing title and file number): DRV-6	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER: Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES: NA
6. DIRECTION OF HOLE: VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: NA
7. THICKNESS OF OVERBURDEN: NA	16. DATE HOLE: STARTED 07/19/91 : COMPLETED 07/19/91
8. DEPTH DRILLED INTO ROCK: NA	17. ELEVATION TOP OF HOLE: -48.1 ft. NGVD
9. TOTAL DEPTH OF HOLE: 19 ft.	18. TOTAL CORE RECOVERY FOR BORING: 19 ft.
	19. SIGNATURE OF INSPECTOR

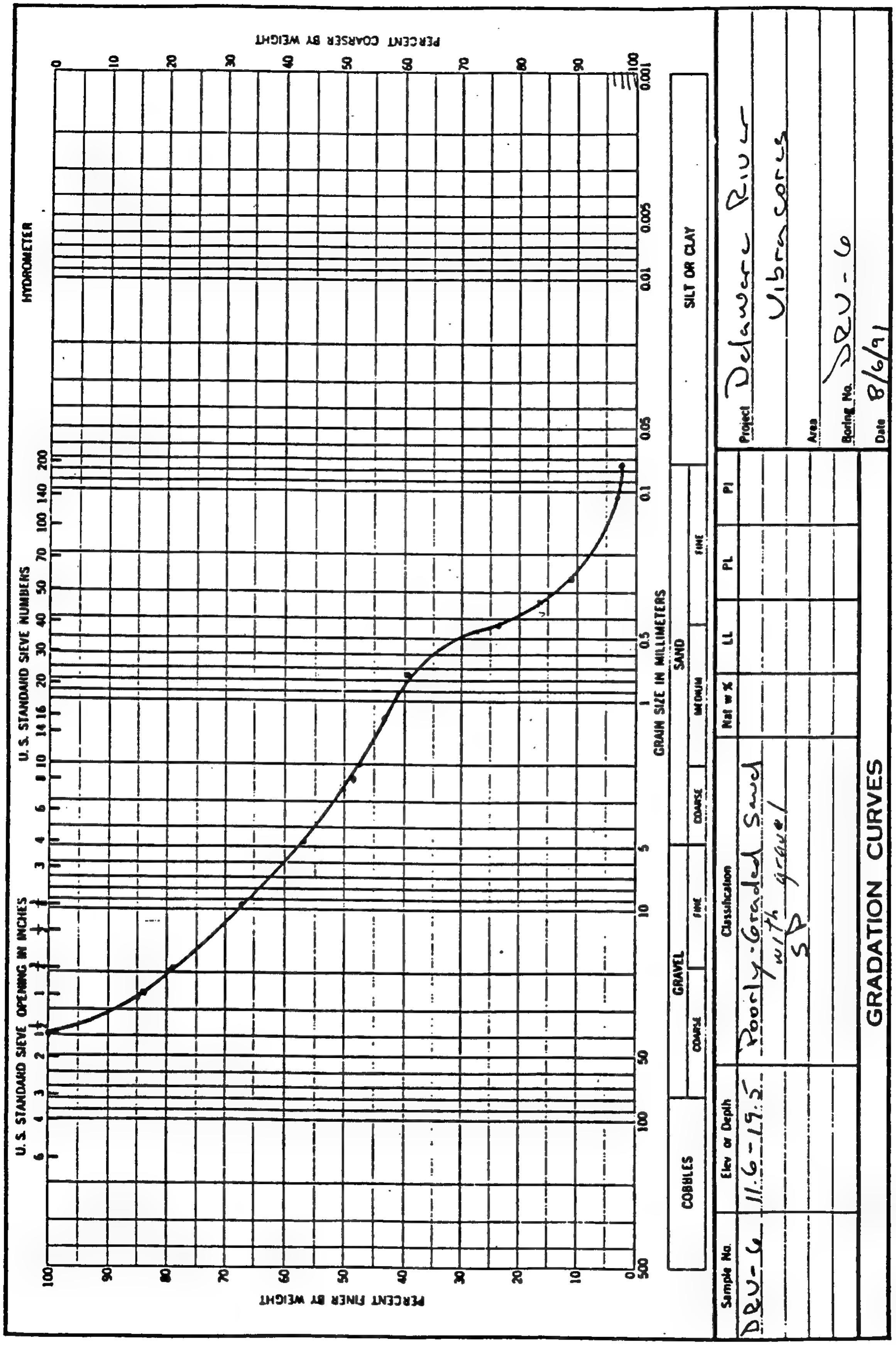
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Grey clayey silt, trace of fine sand Brown clay silt streaks SM-SC			Sample 0 - 5 ft.
	5					
	7.1		Grey clay SM-SC			Sample 7.1 - 10 ft.
	10					
	11.6		Red brown fine to medium sandy gravel with fine to medium sand SP			Sample 11.6 - 15.0 ft.
	14		Coarse sand SP			
	14.4		Grey fine to medium			
	15		.....sandy gravel			
			Grading to brown coarse to fine sandy gravel with coarse to fine sand and scattered small cobbles SP			Sample 11.6 - 9.5 ft.
	19.5					Bottom of recovery

PROJECT: Delaware River Comprehensive Study — HOLE NO. DRV-6


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-6
Elev or Depth
0.0-5.0
Classification
Silty, Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-6
Date 8/12/91
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-6
Silty, Clayey Sand
SM-SC
Project Delaware River Vibracores
Area
Boring No. DRV-6
Date 8/12/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-6
Elev or Depth
11.7-15.0
Classification
Poorly-Graded Sand with gravel
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracore
Area
Boring No. DRU-6
Date 8/12/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-6
11.6-19.5'
Poorly Graded Sand with gravel SP
Project Delaware River Vibracores
Area
Boring No. DRV-6
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

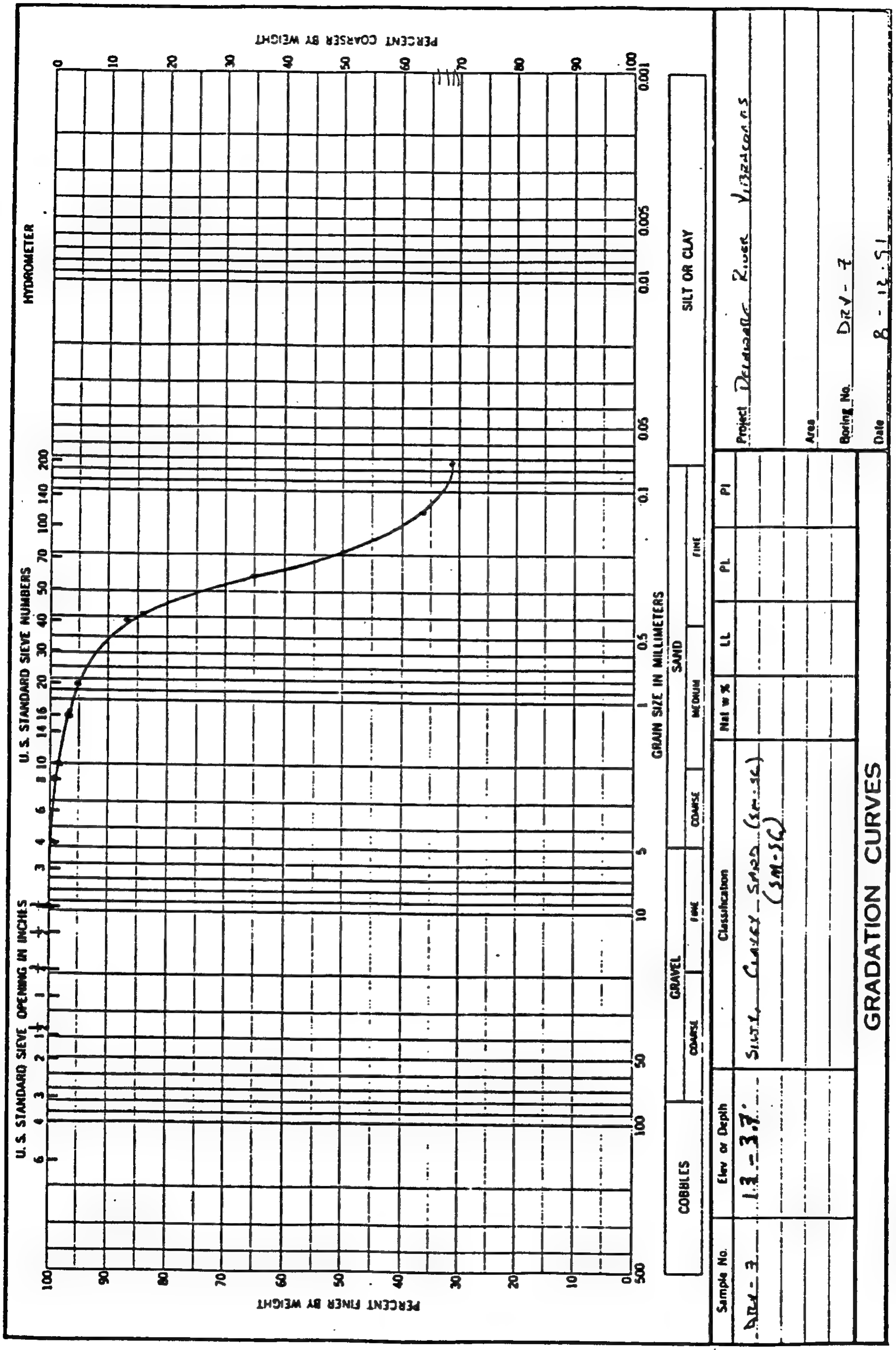
Hole No. DRV-7

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 47' 15.44" 75° 27' 07.24"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-7	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/27/91 : COMPLETED 07/27/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -47.1 ft. NGVD
9. TOTAL DEPTH OF HOLE 3.25 ft.	18. TOTAL CORE RECOVERY FOR BORING 3.25 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	.8		Coarse to medium gravelly sand, one cobble SP			
	1.3		Sandy coarse to fine gravel with medium to fine sand SP			
	2.7		Weathered schist, red 2.3 to 2.8 (iron), green 2.8 to 3.1 red 3.1 to 3.3, green 3.3 to 3.5, red 3.5 to 3.7 SM-SC			Sample 1.3 - 2.7 ft.
	3.25		Saprolite of Chlorite schist	Bedrock		
			Bottom of recovery 3.25 ft.			

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-7


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-3
13-37'
SILTY CLAYEY SAND (SM-SC)
(SM-SC)
Project Delaware River
Area
Boring No. DRV-7
Date 8-12-51
GRADATION CURVES
ENG FORM 1 MAY 63 2087

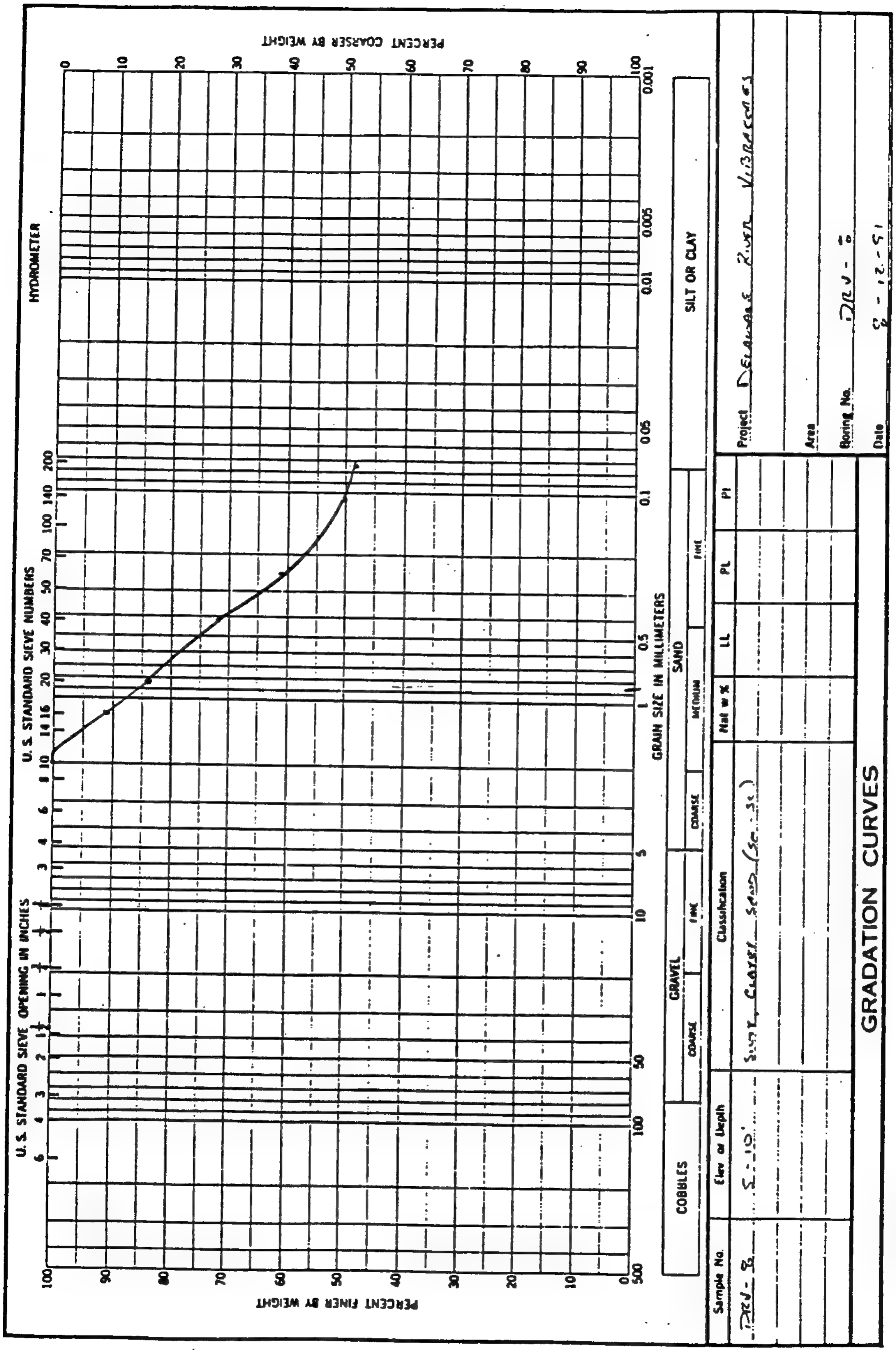
Hole No. DRV-8

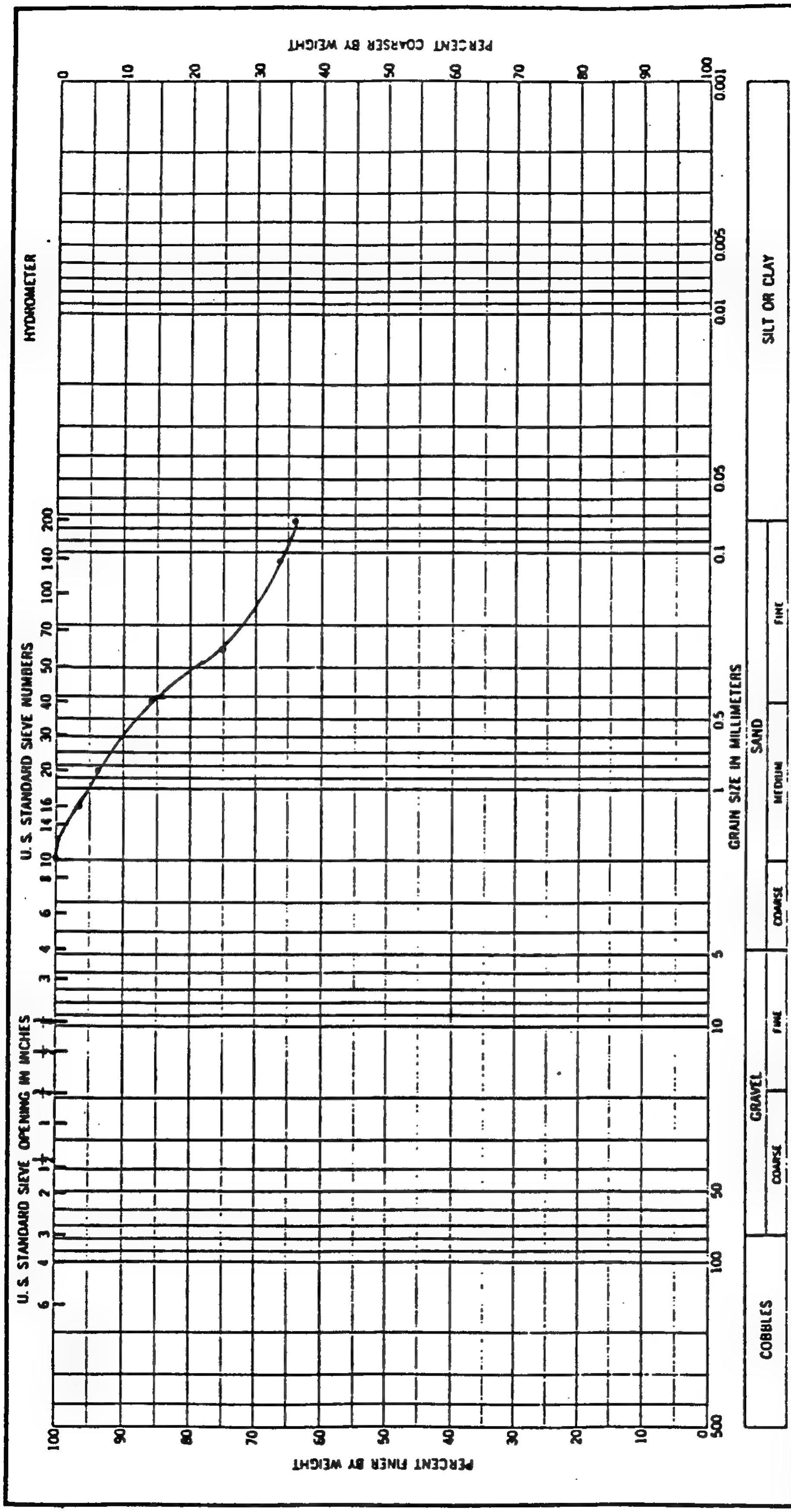
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 45' 47.83" 75° 28' 36.82"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/27/91 : COMPLETED 07/27/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -48.2 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 19 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0–5		Gray silty clay SM-SC			Sample 0 - 5 ft. Sand lenses in sample
	5–10		Fine sand lenses at 8 ft. SM-SC			Sample 5 - 10 ft. Sand lenses in sample
	10–15		Fine to medium sand lenses <0.5 inches in at 11.4 to 11.4 CL			Sample 10 - 15 ft.
	15–19		Coarse to fine sandy at 15.6 ft GM-GC			Sample 15 - 19 ft. Sample of sandy layer
	19					Bottom of recovery

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-8


PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-8	10-15'	Clay CL		44.7	25.3	19.4

Project Delaware River Vibracores

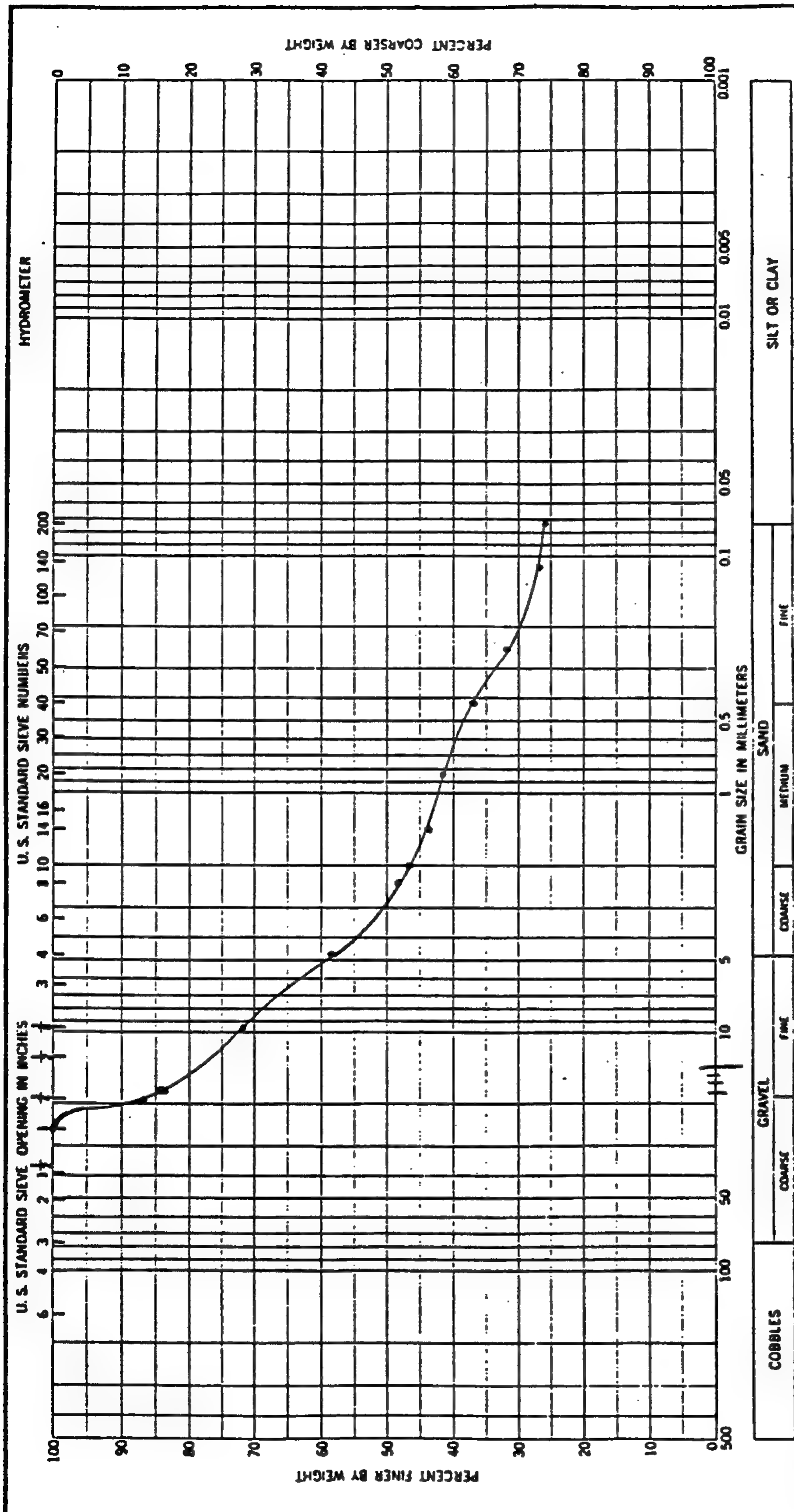
Area

Boring No. DRV-8

Date 8-12-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV - 8	15 - 15'	Silty Clayey Gravel (GM-GC)				

Project Delaware River Vibracores

Area

Boring No. DRV - 8

Date 8 - 12 - 71

GRADATION CURVES

ENG FORM 1 MAY 63 2087

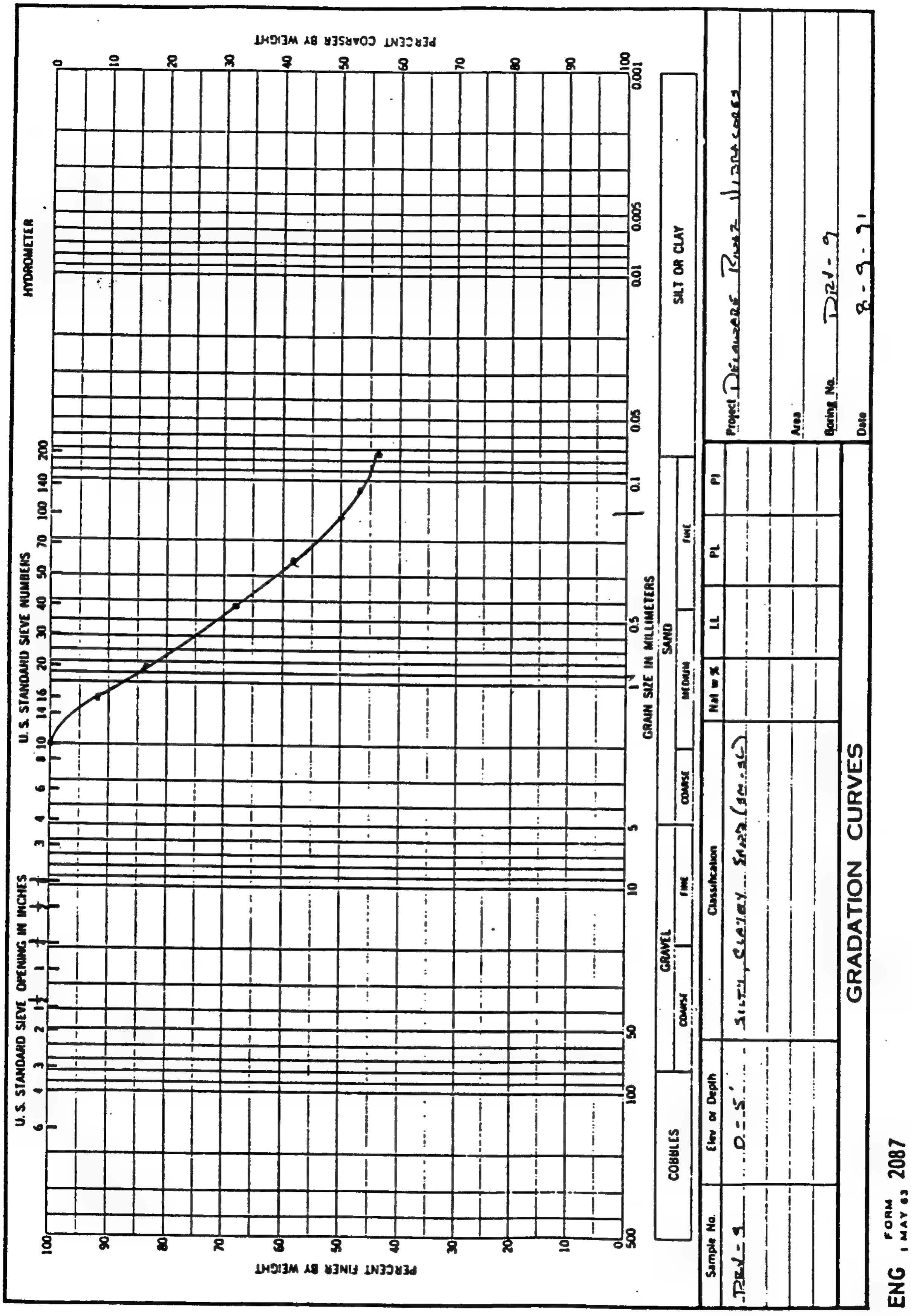
Hole No. DRV-9

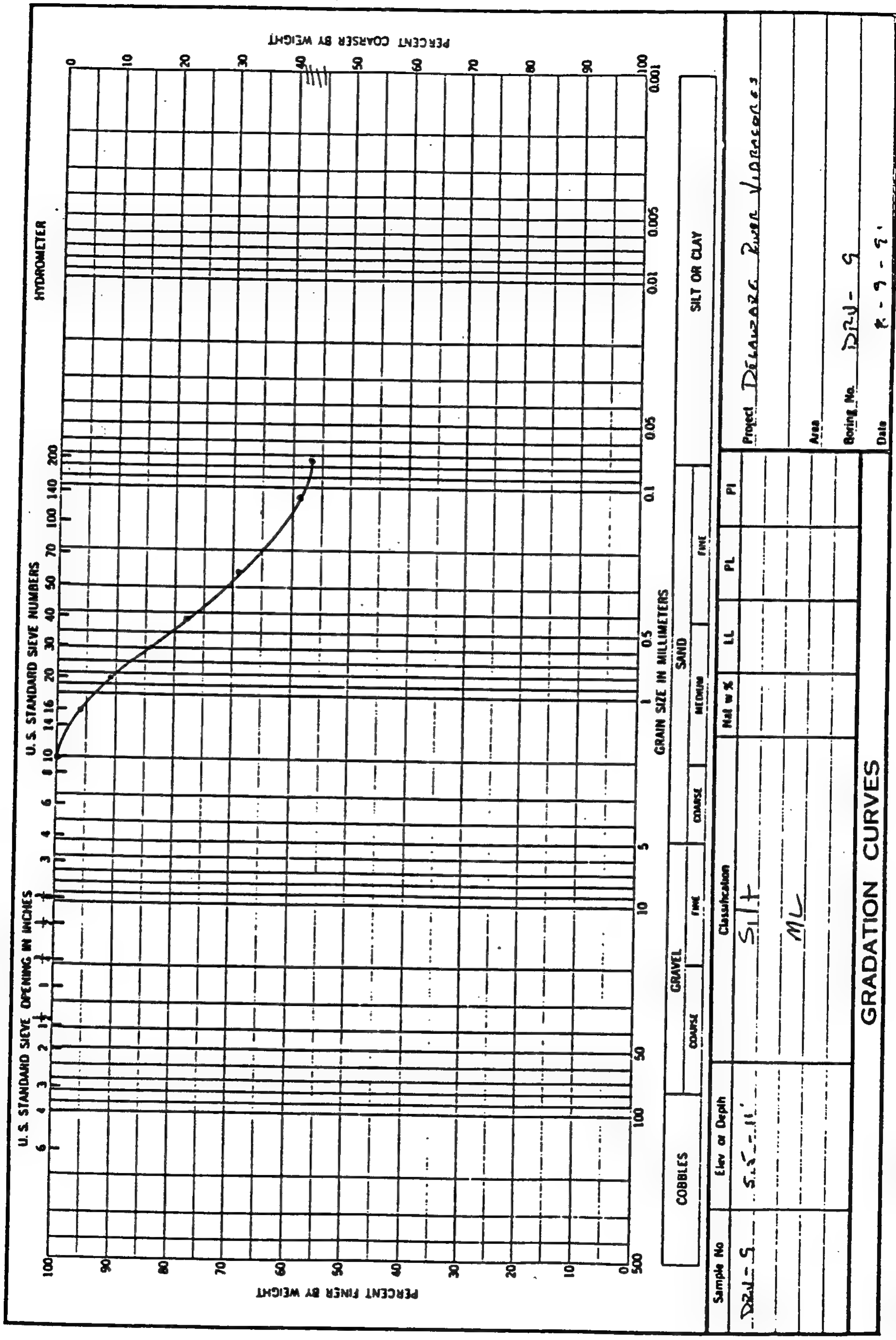
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

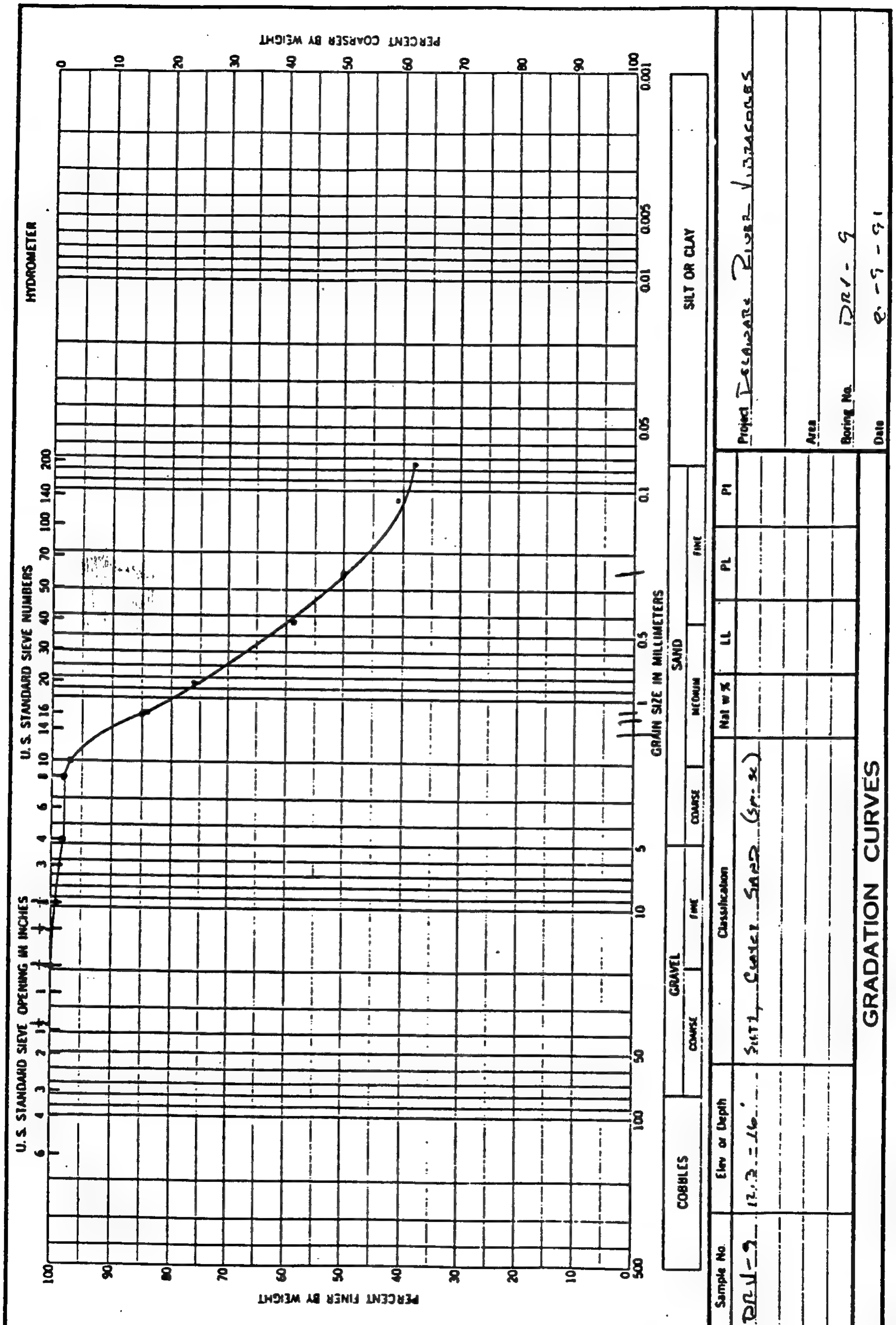
PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 44' 6.62 75° 30' 3.34"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-9	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/19/91 : COMPLETED 07/19/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -49.9 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 20 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Grey silty clay, sand lenses SM-SC			
	1					Sample 0 - 5 ft.
	2.3		Coarse sand layer			
	5.5		ML			Sample 5.5 - 11 ft.
	11					
	13		SM-SC			Sample 12.3 - 16 ft.
	16.4					16.4 Bottom of recovery

PROJECT Delaware River Comprehensive Study HOLE NO. DRV-9


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
MEDIUM
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
D2U-5
Silt
ML
Project
Area
Boring No.
D2U-5
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



ENG FORM 1 MAY 63 2087

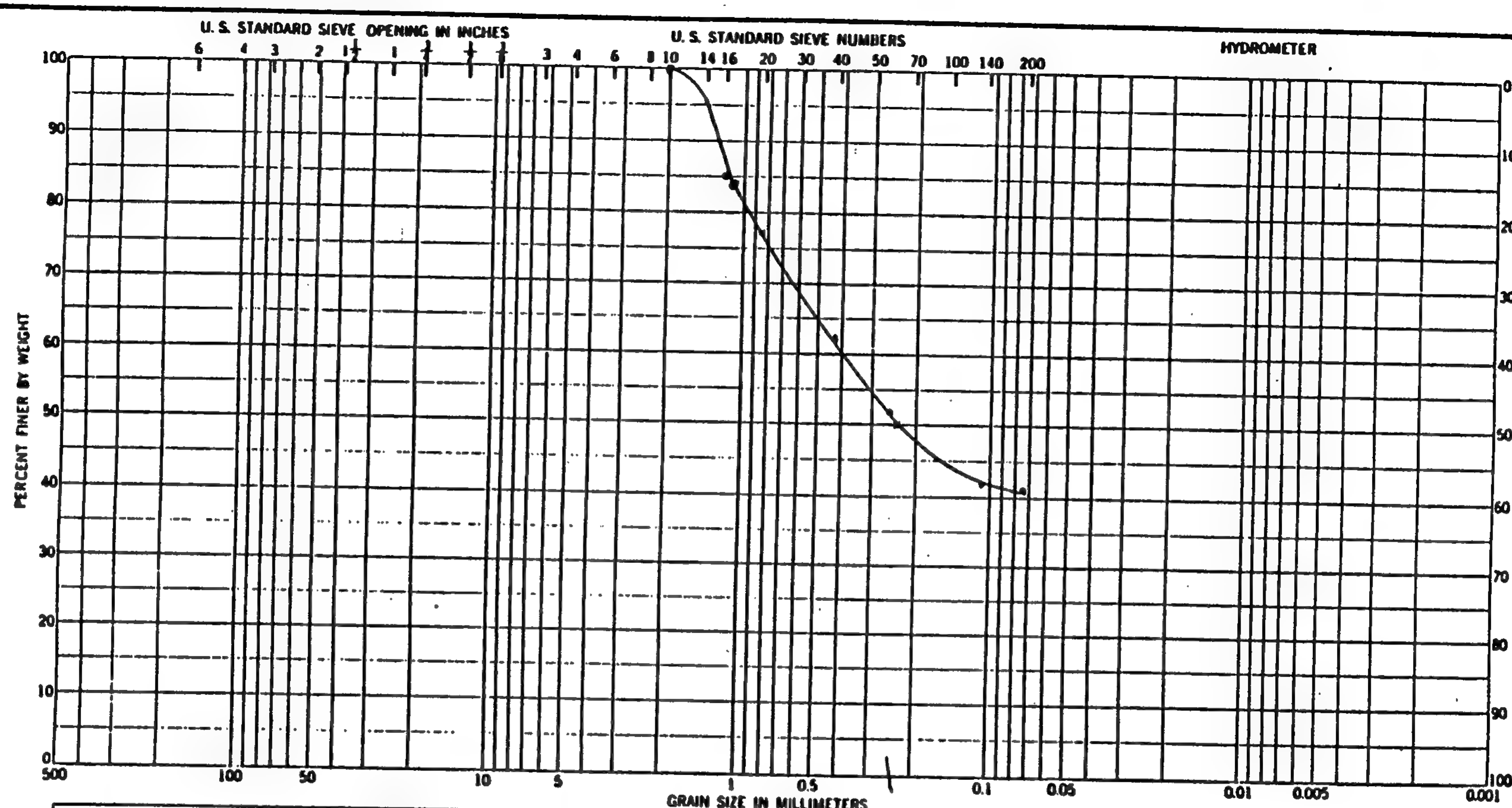
Hole No. DRV-10

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 42' 34.12" 75° 30' 37.77"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-10	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED : NA :
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
	15. ELEVATION GROUND WATER NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	16. DATE HOLE : STARTED 07/28/91 : COMPLETED 07/28/91
7. THICKNESS OF OVERBURDEN NA	17. ELEVATION TOP OF HOLE -48.2 ft. NGVD
8. DEPTH DRILLED INTO ROCK NA	18. TOTAL CORE RECOVERY FOR BORING 20 ft.
9. TOTAL DEPTH OF HOLE 20 ft.	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Grey silty clay SM-SC			Sample 0 - 5 ft. Sand lenses in sample
	1					
	2					
	3 .1		Fine sand 3.1 ft, thin sand surface at 6.5 ft, 7.5, 7.6, 8.5, 9.2, 10.5, 11.3, 12.65, 13.1 coarse to medium sand at 6.2 to 6.3, 6.6, 7.9 to 7.8, 8.0 to 8.3			
	4					
	5		Fine sand pocket at 9.2 to 9.3 Medium to fine sand at 10 ft., 11.1 to 11.4, 12.4 to 12.55 SM-SC			Sample 5 - 10 ft.
	6					
	7					
	8					
	9					
	10					
	11					
	12 .4					
	13 .3		Interbedded fine sand and silty clay .05 sand, 1.5 silty organics in layers at 14.5, 14.75 and 14.9 SM-SC			Sample 13.3 - 15 ft.
	14					
	15		Silty clay with sand surface - organics at 16.25 SM-SC			
	16 .5		Medium to fine sand SP			
	.9 17		Grey silt clay with sand lenses at 17.95 to 18.05, 18.35, 18.65, 19.35, 19.4 SM-SC			
	18					
	19		Black organic at 19.7 to 19.9			

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-10



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-10	0-5'	SILTY, CLAYEY SAND (SM-SC)				

Project DELAWARE RIVER VIBRACORES

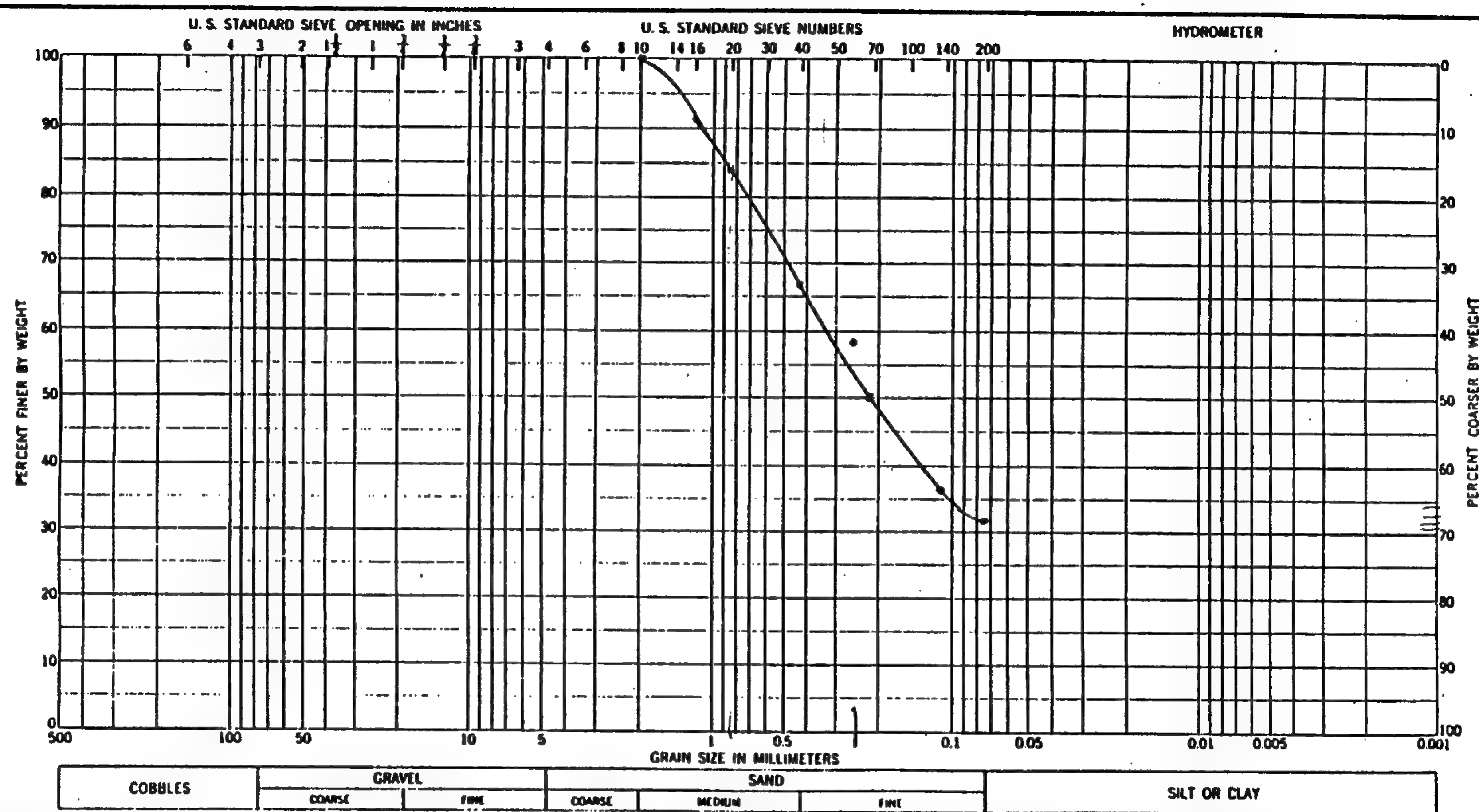
Area

Boring No. DRV-10

Date 8-7-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV -10	5-10'	SILTY, CLAYEY SAND (SM-SC)				

Project DELAWARE RIVER VIBRACORES

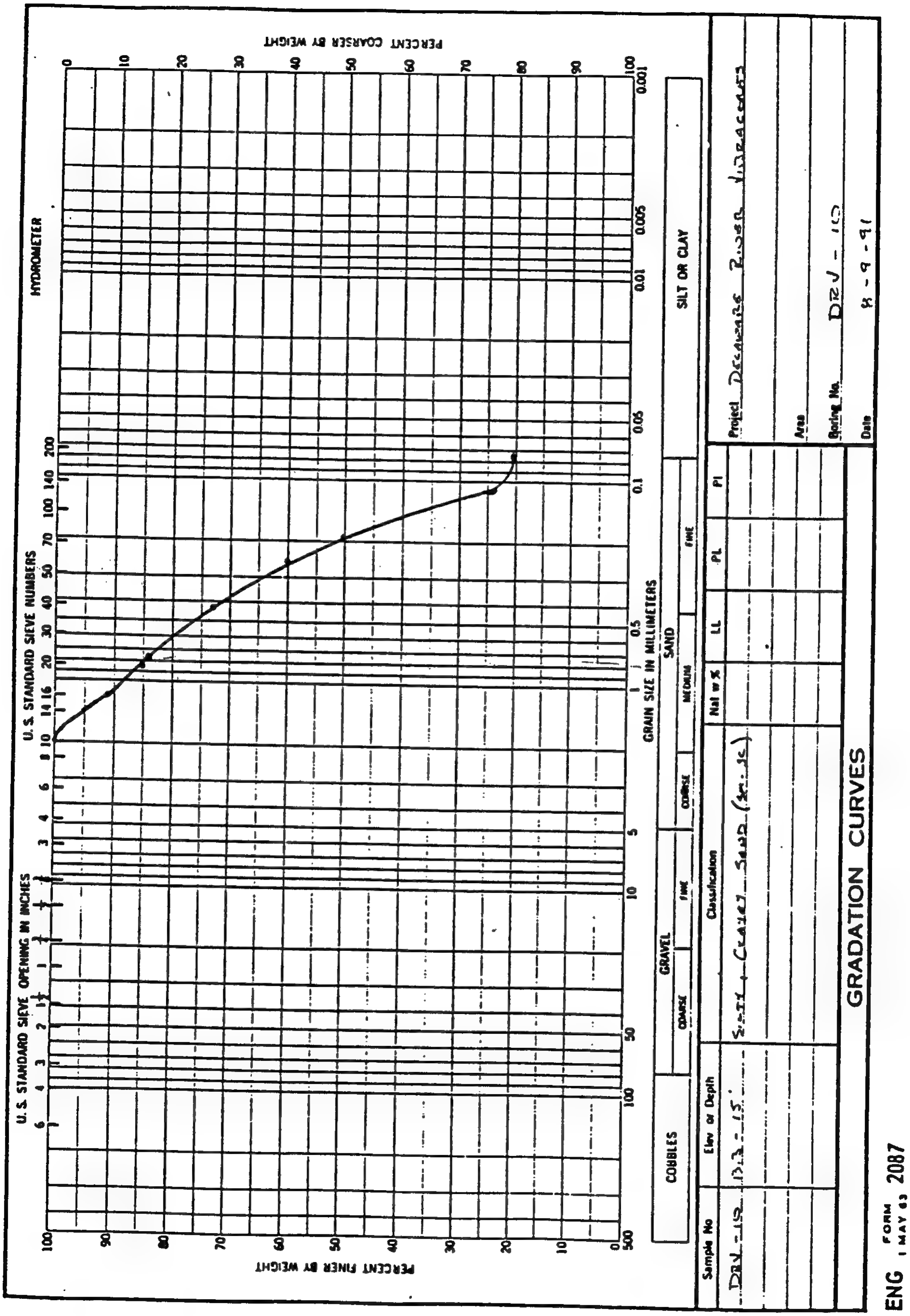
Area

Boring No. DRV - 10

Date 8 - 9 - 91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
DRV - 10
Date
8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

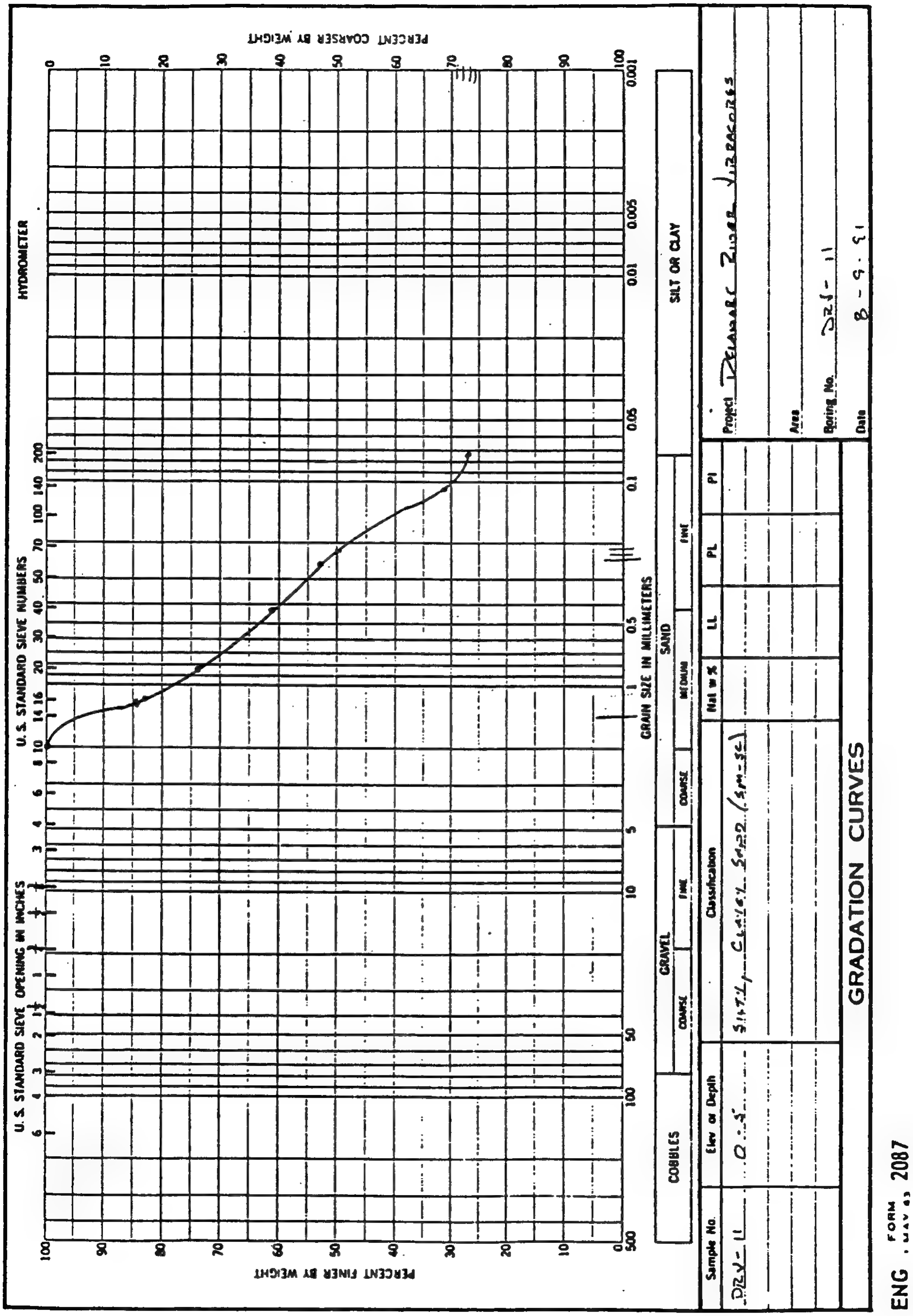
Hole No. DRV-11

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

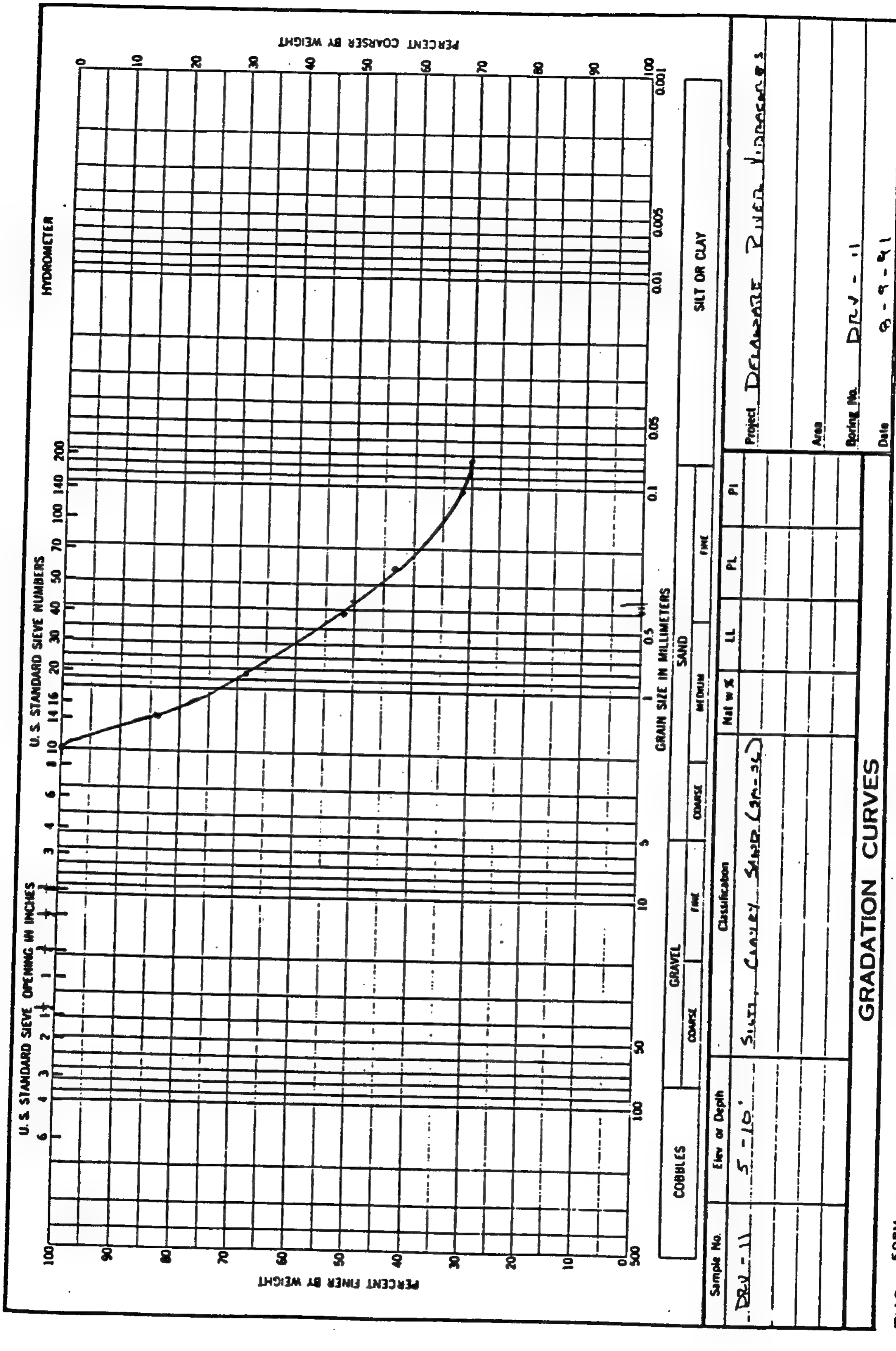
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 39' 15.12" 75° 32' 47.60"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED NA : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/28/91 : COMPLETED 07/28/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -47.2 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 19 ft.
	19. SIGNATURE OF INSPECTOR

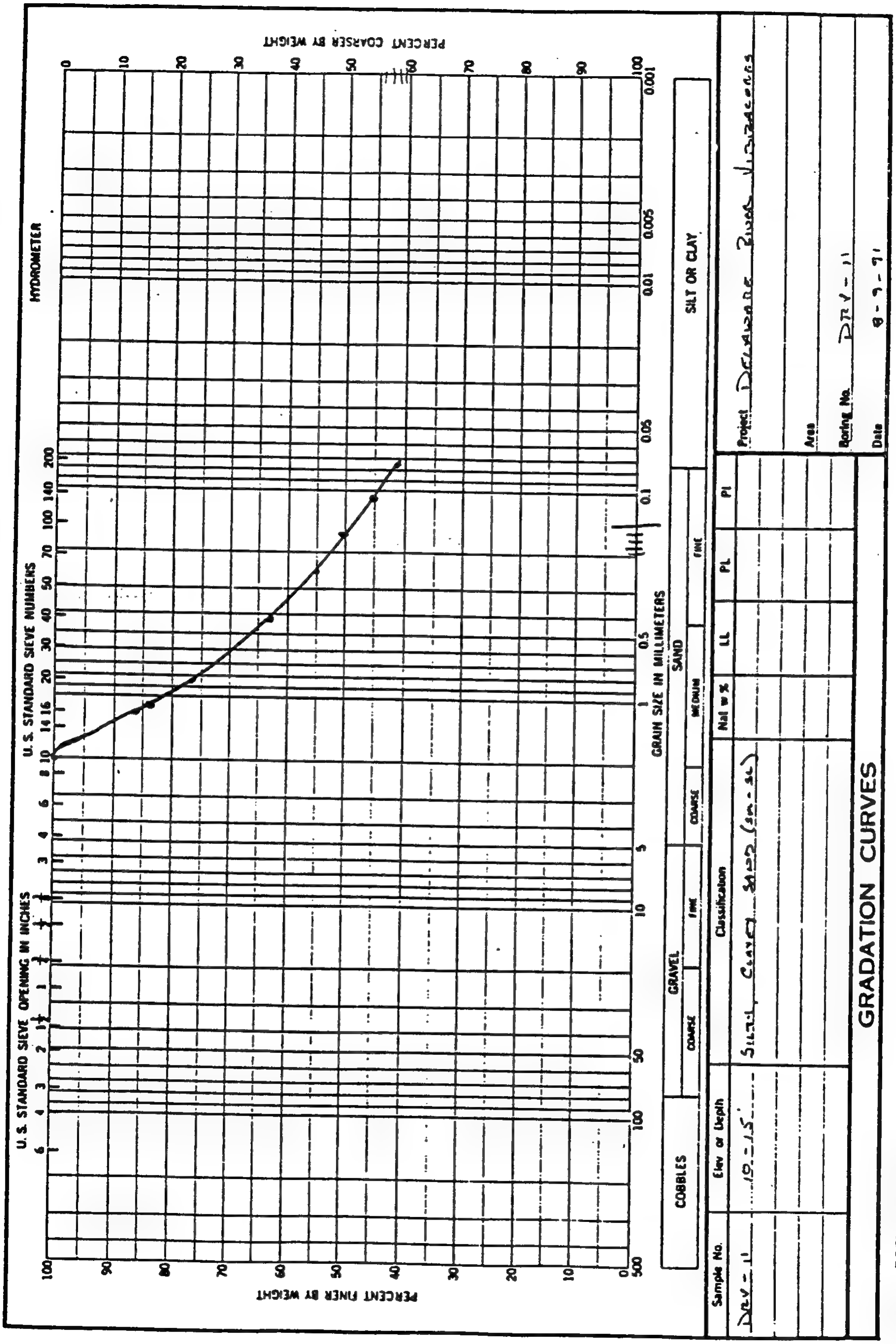
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Grey clayey silty sand SM-SC			
	2					Sample 0 - 5 ft.
	5					
	6		SM-SC			Sample 5 - 10 ft.
	9.3		Sand lenses at 9.3 ft. (.01)			
	10					
	10.6		Light color streak - 25° dip 10.65 SM-SC			
	11.7		Fine sand 11.7, 12.3, 13.6, 14.0 at 25° dip Few sandy faces at 25° dip			Sample 10 - 15 ft.
	14–15		Medium to fine sand layer at 25° dip, 15.35 to 15.46, 16.05 to 16.07, 16.48 to 16.50 16.97 to 17.0, 18.23 to 18.26, 18.31 to 18.34			
	16		SM-SC			Sample 15 - 19 ft.
	19					19 ft. Bottom of recovery

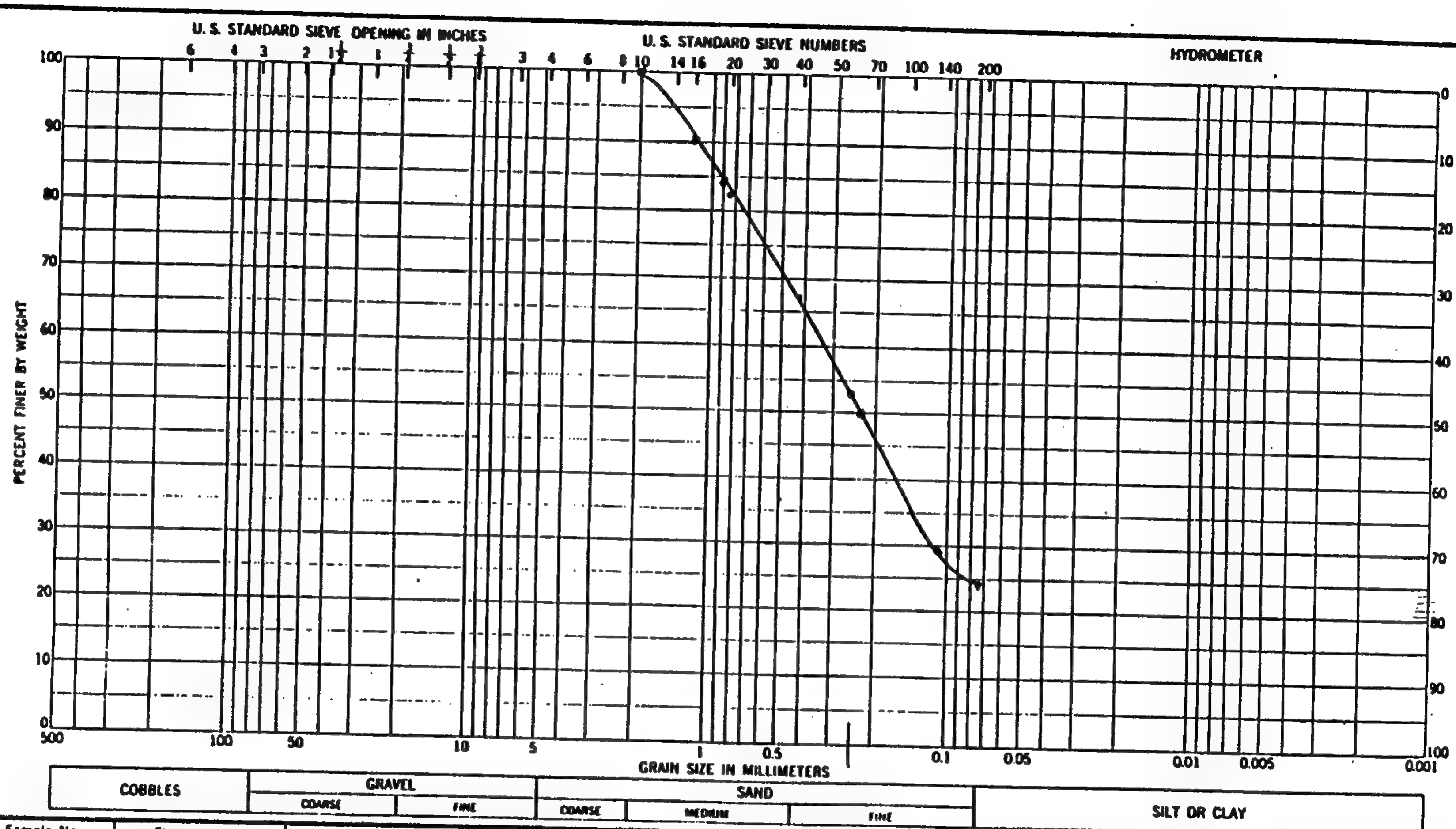
PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-11



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-11
0-.5'
Silty, Clayey Sand (SM-SC)
Project Delaware River Vibracores
Area
Boring No. DRV-11
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRV-11
Elev or Depth
5-10'
Classification
Silty Clayey Sand (SM-SC)
Nat w %
LL
PL
PI
Project Delaware River
Area
Boring No. DRV-11
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-11	15-15'	Silty, Clayey Sand (SM-SC)				

Project: Delaware River Vibracores
Area:
Boring No.: DRV-11
Date: 8-9-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

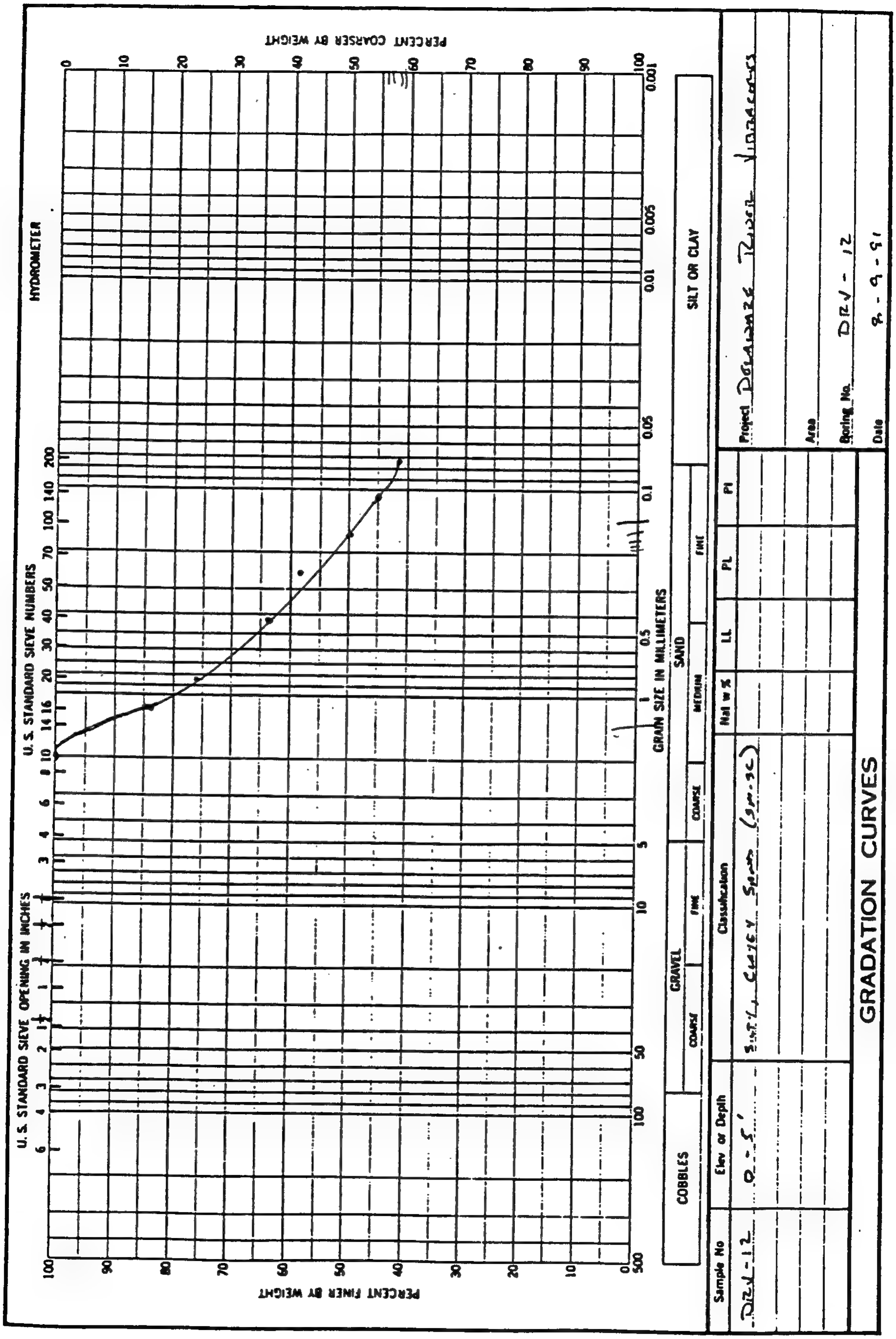
Hole No. DRV-12

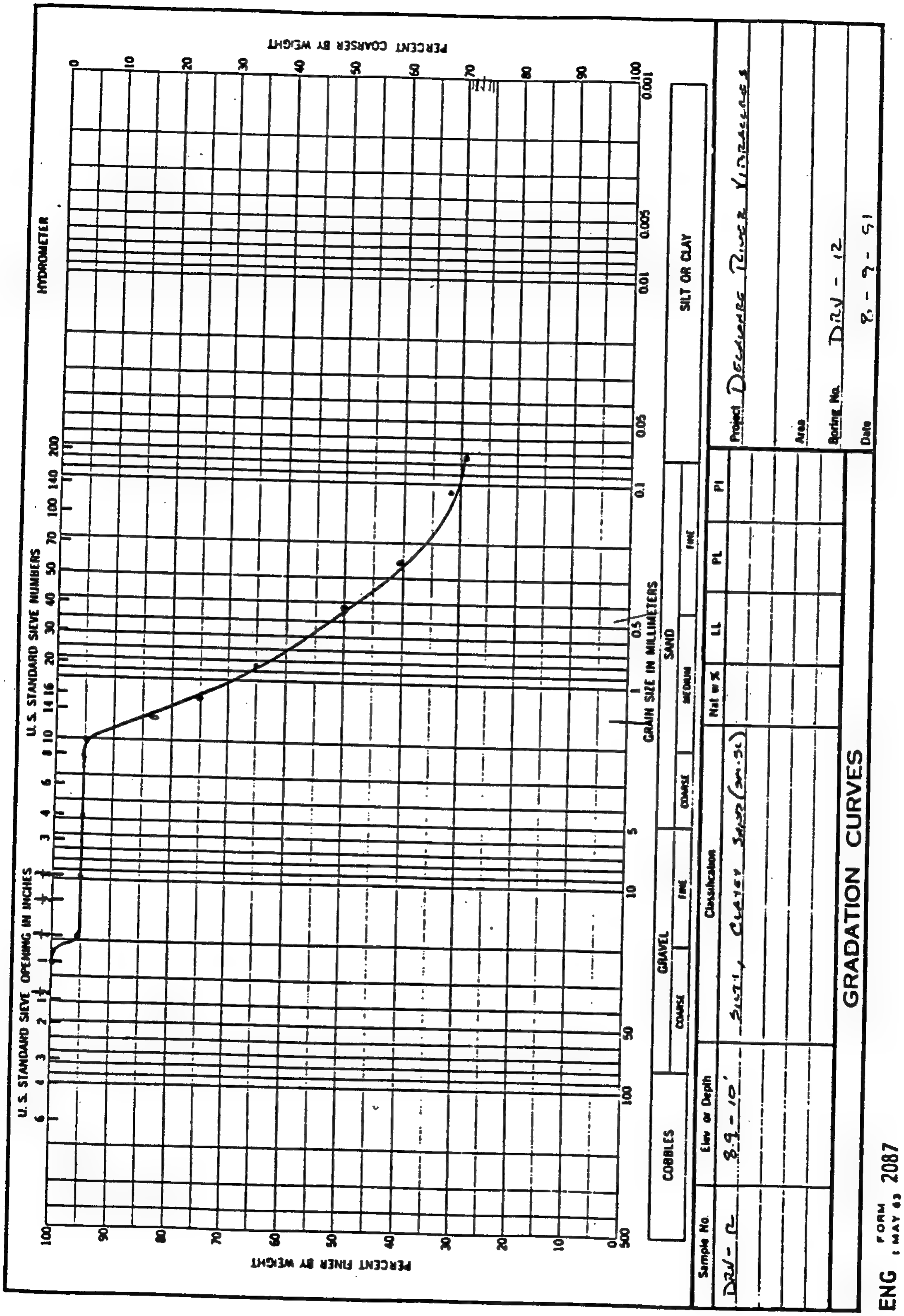
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT: Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT: Vibracore
2. LOCATION (Coordinates or Station): 39° 34' 07.17" 75° 32' 59.47"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL: NA
4. HOLE NO. (As shown on drawing title and file number): DRV-12	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED : UNDISTURBED
5. NAME OF DRILLER: Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES: NA
6. DIRECTION OF HOLE: VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: NA
7. THICKNESS OF OVERBURDEN: NA	16. DATE HOLE: STARTED 07/28/91 : COMPLETED 07/28/91
8. DEPTH DRILLED INTO ROCK: NA	17. ELEVATION TOP OF HOLE: -44.5 ft. NGVD
9. TOTAL DEPTH OF HOLE: 20 ft.	18. TOTAL CORE RECOVERY FOR BORING: 17.7 ft.
	19. SIGNATURE OF INSPECTOR

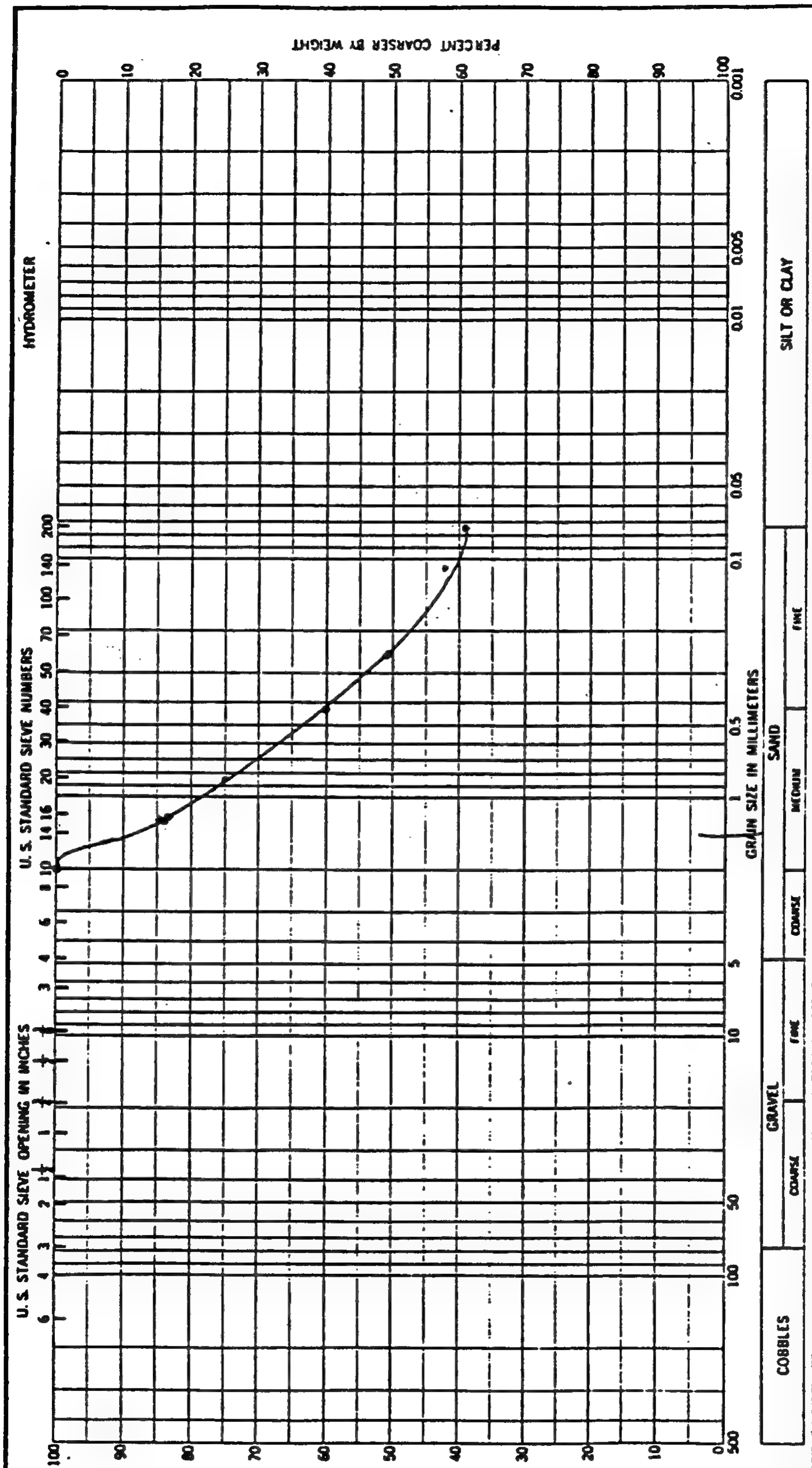
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Grey clay to silt clay Organic layers .01 ft. at 2.5, 4.6, 5.95 to 6.0, 6.96 to 7.8 SM-SC			Sample 0 - 5 ft. Sand lenses in sample
	9		SM-SC			Sample 8.9 - 10 ft.
	10		Grey silt firm SM-SC			Sample 10 - 15 ft. Sandy lenses in sample
	13		Sand lense at 13.0 Sand layer at 13.75 Sand faces occassional			
	16		ML			Sample 15 - 17 ft.
	17.7					17.7 ft. Bottom of recovery

PROJECT: Delaware River Comprehensive Study | HOLE NO. DRV-12


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-12
Elev or Depth
0-5'
Classification
Silty, Clayey Sand (SM-SC)
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-12
Date 8-9-91
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-12	10-15'	Silty, Clayey Sand (SM-SC)				

Project: Delaware River Vibracores

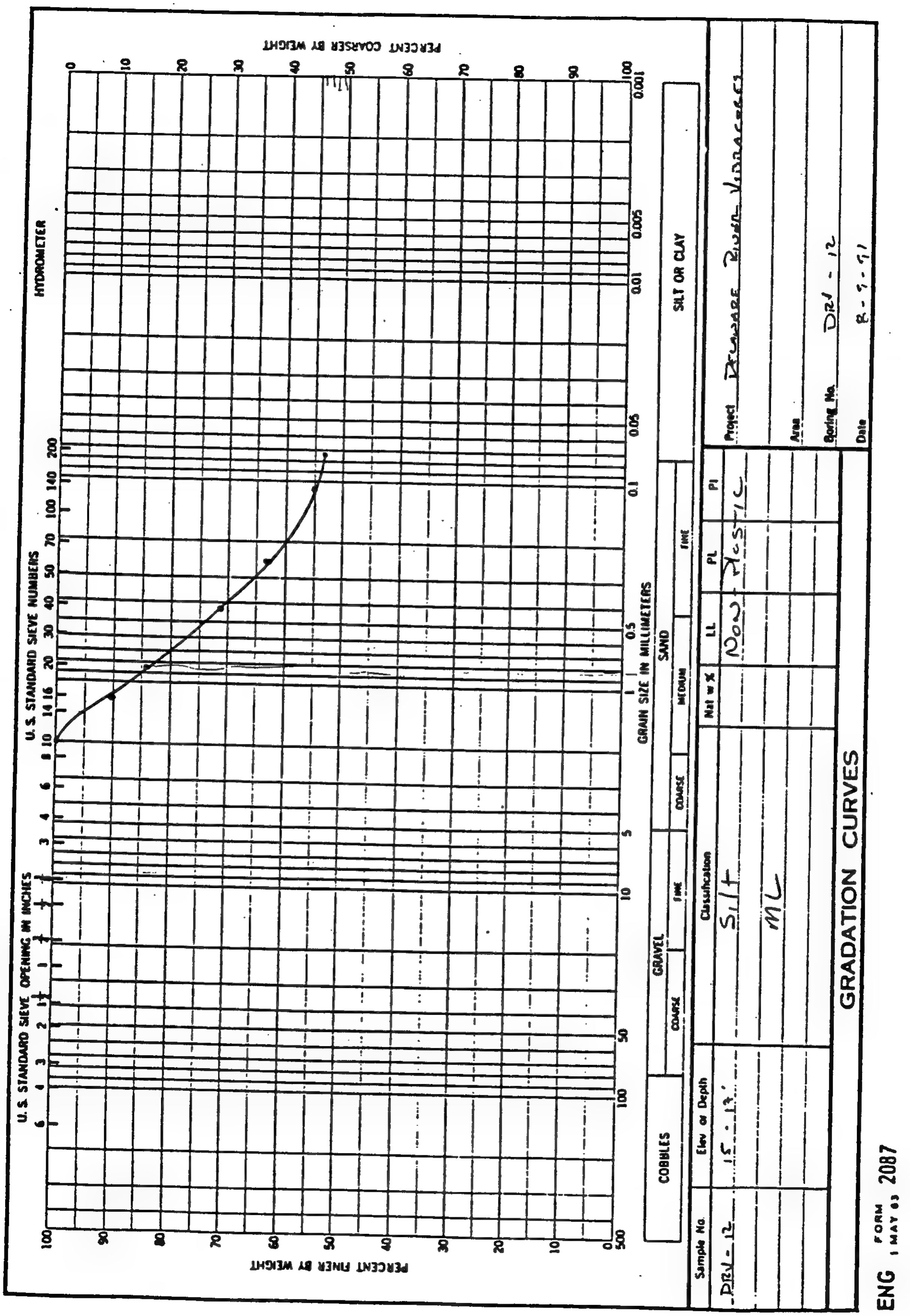
Area:

Boring No. DRV-12

Date 8-9-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

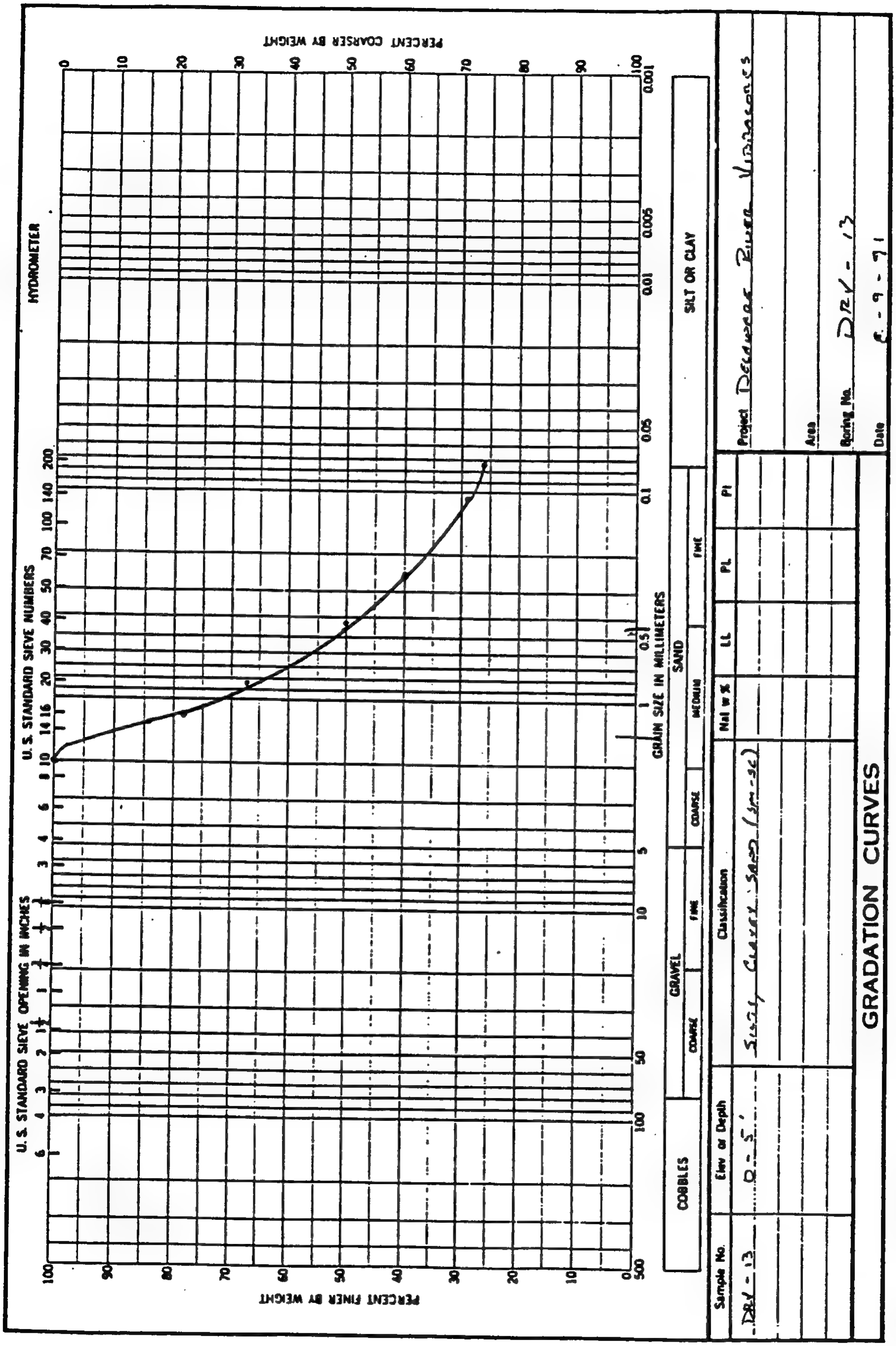

GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRI - 12
15' - 17'
Silt
ML
Non Plastic
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

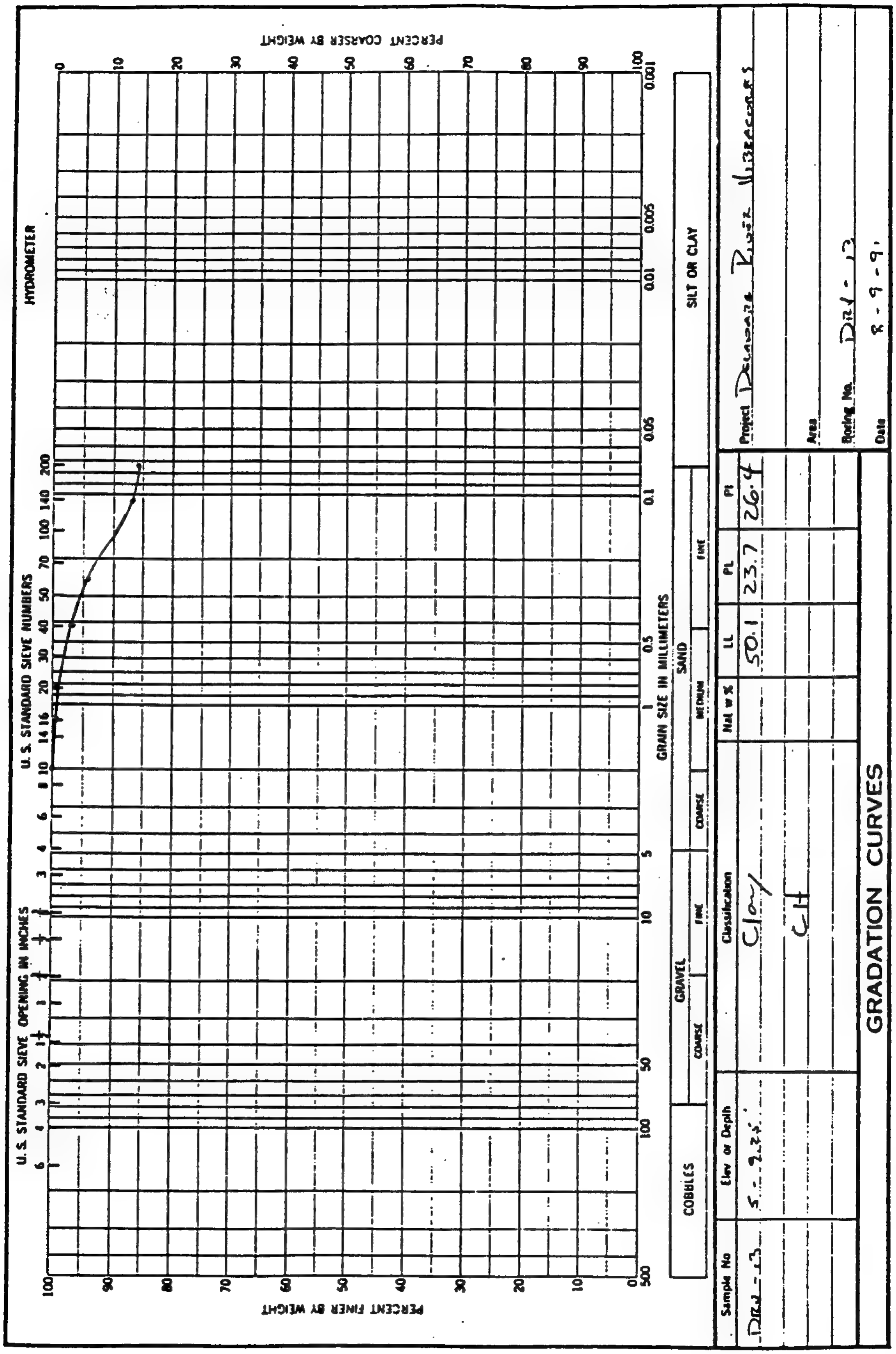
PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station) 39° 28' 7.65" 75° 33' 44.98"	12. MANUFACTURER'S DESIGNATION OF DRILL NA
3. DRILLING AGENCY Buchart-Horn, Inc.	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
4. HOLE NO. (As shown on drawing title and file number) DRV-13	14. TOTAL NUMBER CORE BOXES NA
5. NAME OF DRILLER Ocean Survey, Inc.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE : STARTED 07/19/91 : COMPLETED 07/19/91
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	17. ELEVATION TOP OF HOLE -50.7 ft. NGVD
7. THICKNESS OF OVERBURDEN NA	18. TOTAL CORE RECOVERY FOR BORING 20 ft.
8. DEPTH DRILLED INTO ROCK NA	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE 20 ft.	

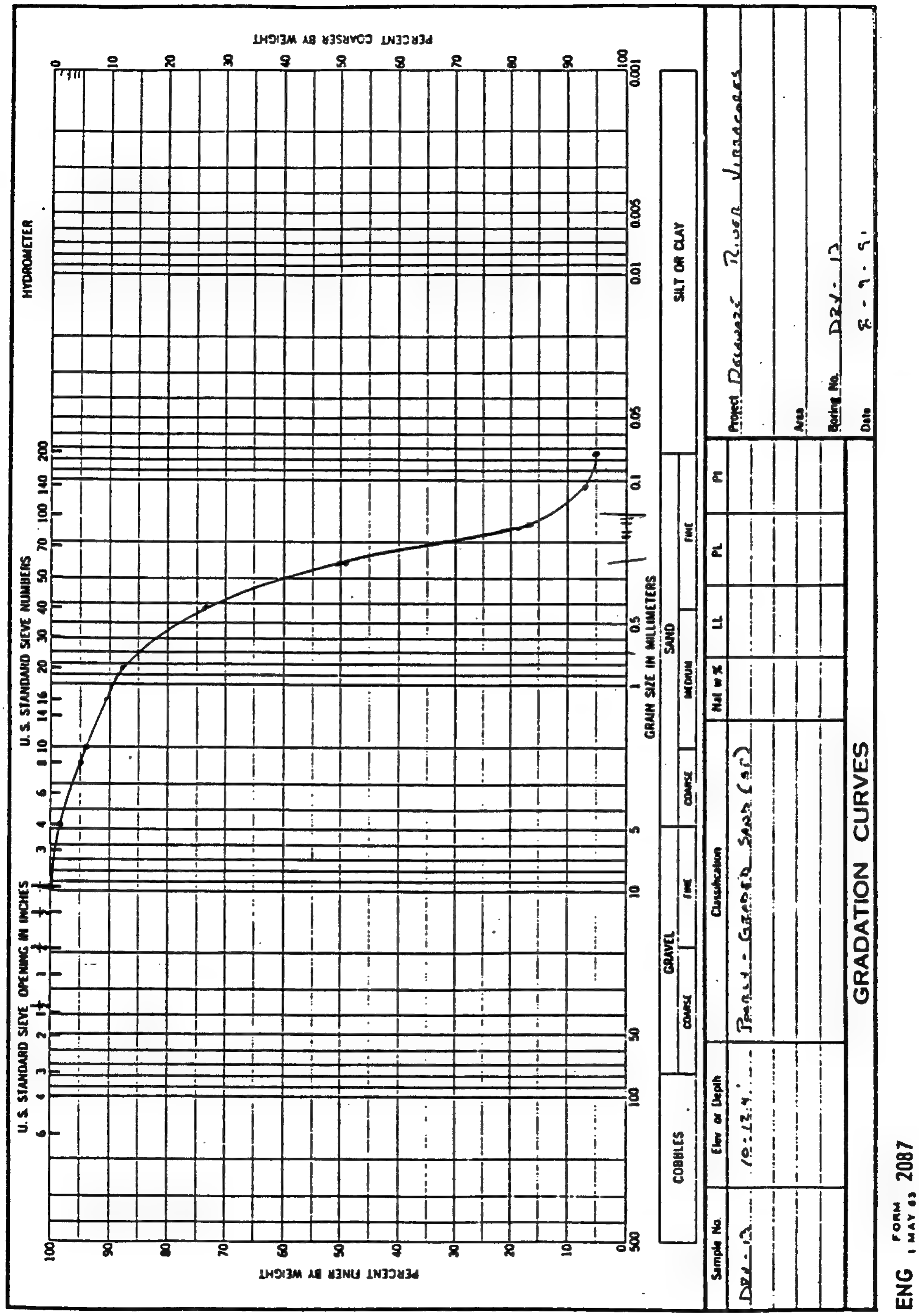
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0–5		Grey clay to silt clay, sand faces intermittently Organics in clay at 1.92, 2.74 and 3.3 to 3.6 CL-SC			Sample 0 - 5 ft.
	5–9.25		Organics bits random			Sample 5 - 9 1/4 ft.
	9.25–10		Sand, very wet Dryer toward bottom SP			Sample 9 1/4 - 10 ft.
	10–12.5		SP			Sample 10 - 12.4 ft.
	12.5–15		Grey gravelly sand grading down to sandy gravel Medium to fine sand medium to fine gravel SM-SC			Sample 12.4 - 15 ft.
	15–17					
	17–20		Grey gravelly coarse to fine sand with medium to fine gravel			Sample 17.1 - 20 ft. No gravel in sample

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-13

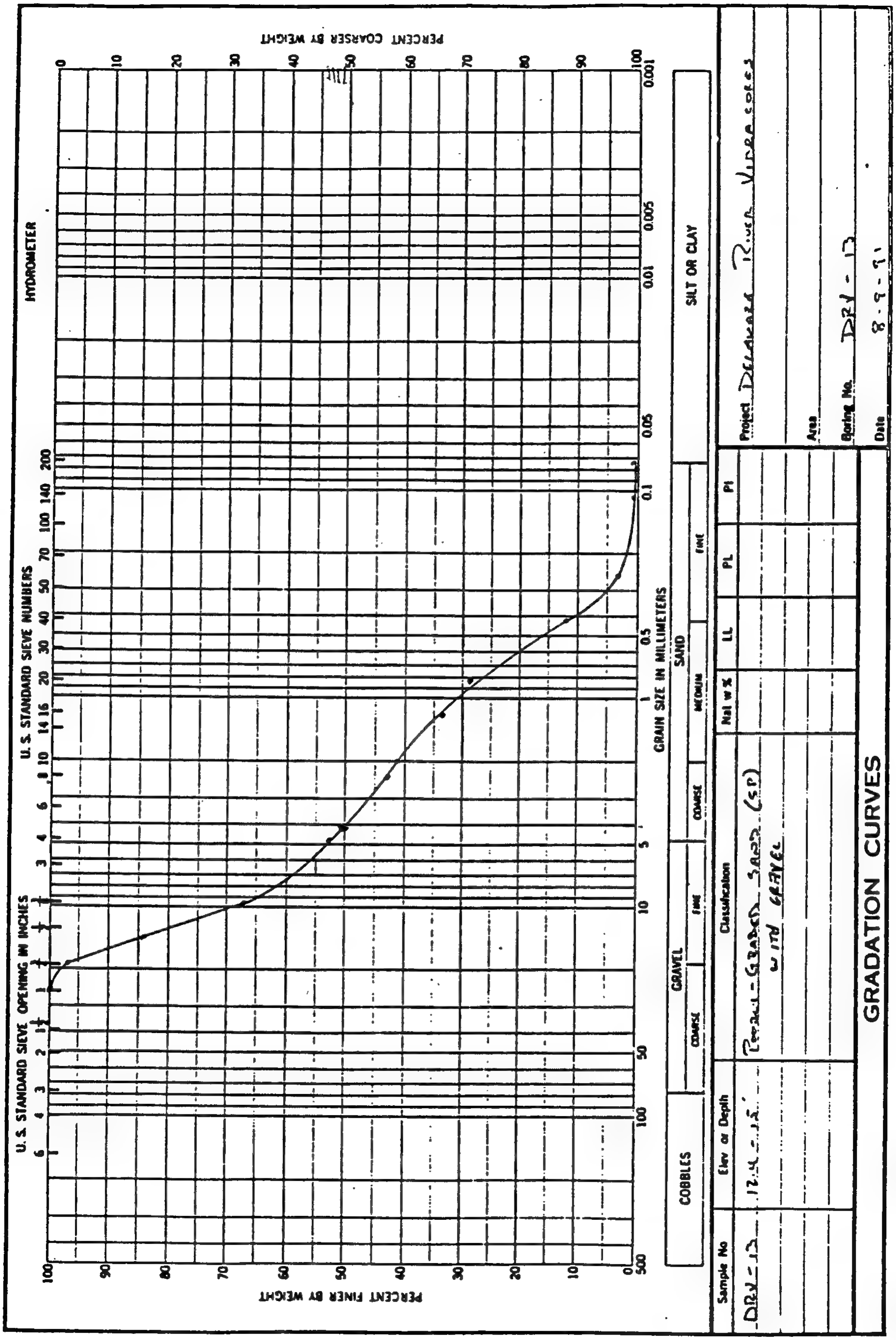


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRY-13
Elev or Depth 0-5'
Classification Silty Clayey Sand (SM-SC)
Nat w % LL PL PI
Project Delaware River Vibracores
Area
Boring No. DRY-13
Date 8-9-91
ENG FORM 1 MAY 63 2087

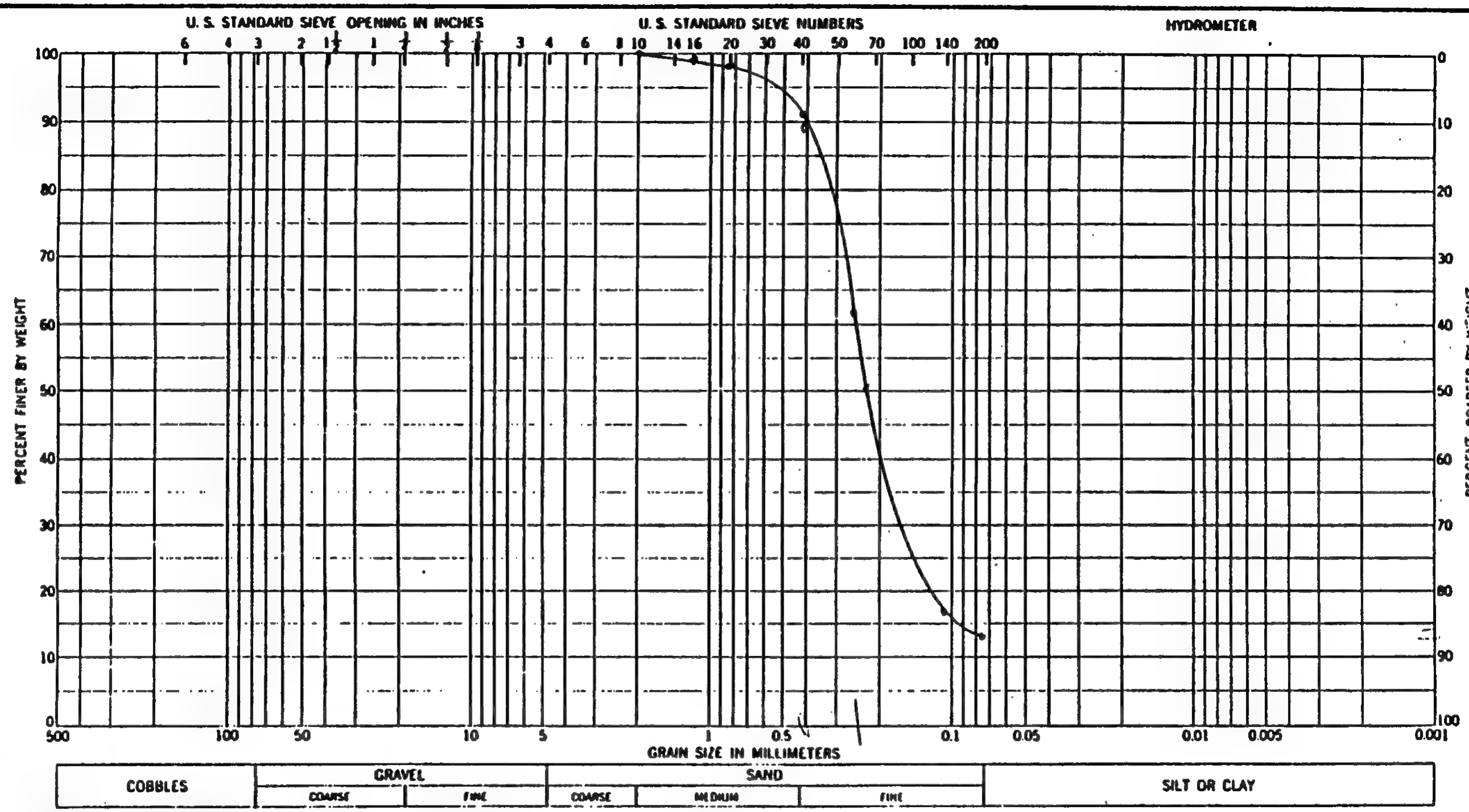

U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRW-13
Elev or Depth
5-9.35'
Classification
Clay
CH
Nat w %
LL
50.1
PL
23.7
PI
26.4
Project Delaware River Vibracores
Area
Boring No. DRW-13
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRY-13
Elev or Depth
12.4 - 15'
Classification
Poorly-Graded Sand (SP) with Gravel
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRY-13
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-13	17.1-20'	Silty Clayey Sand (SM-SC)				

Project Delaware River Vibracores

Area

Boring No. DRV-13

Date 8-9-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

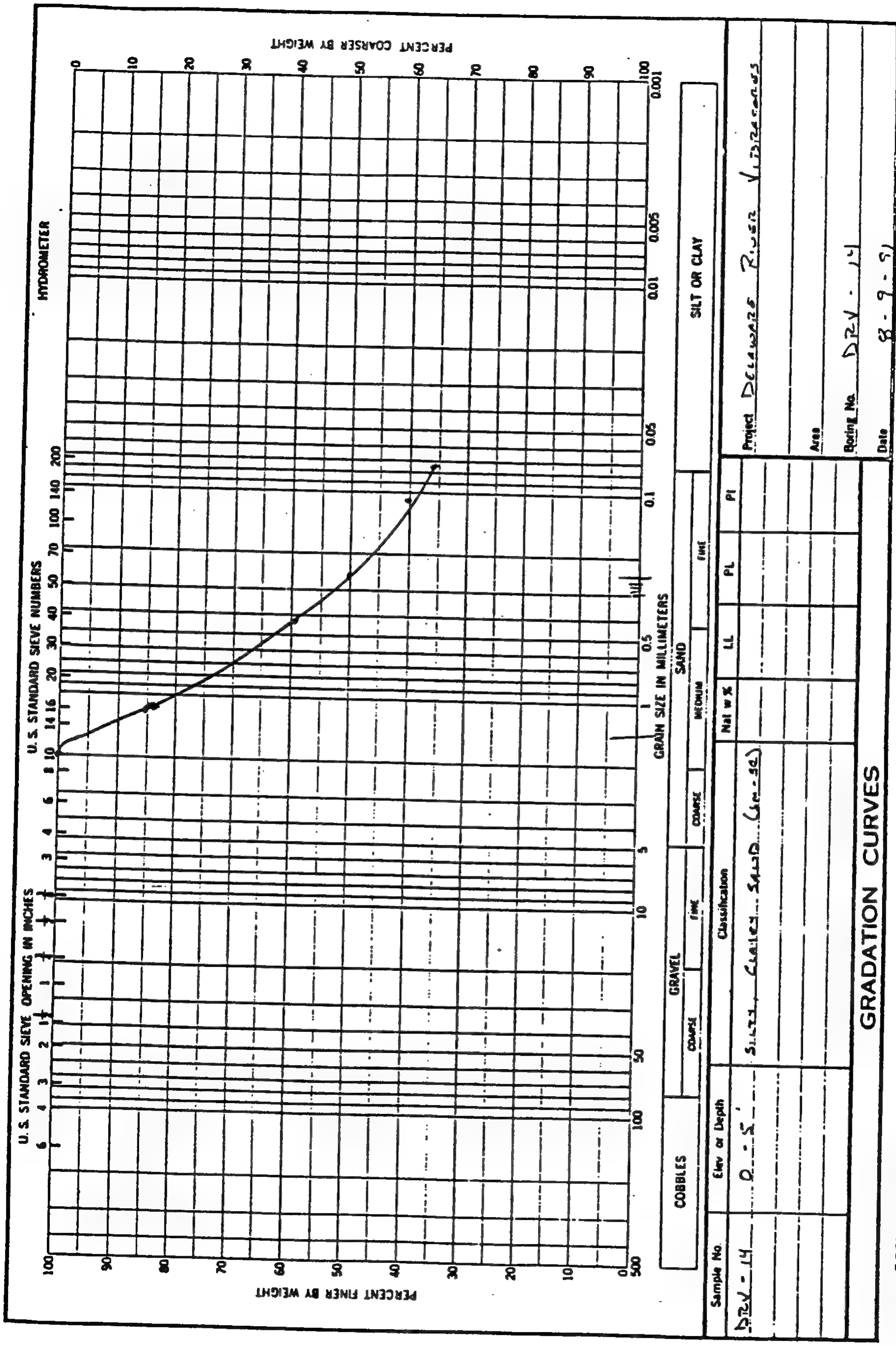
Hole No. DRV-14

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

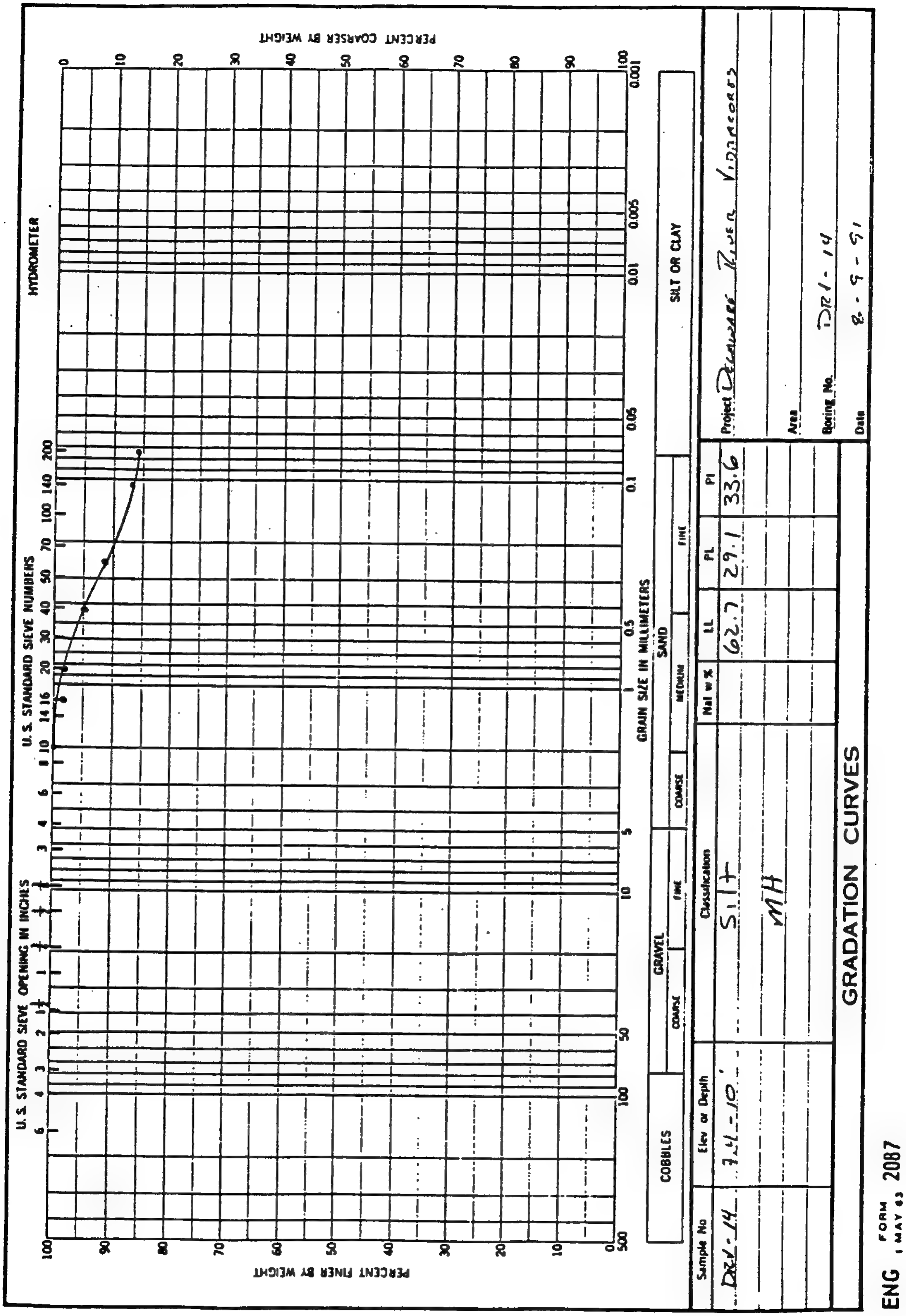
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 20' 49.15" 75° 25' 50.09"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-14	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/29/91 : COMPLETED 07/29/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -42.7 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 20 ft.
	19. SIGNATURE OF INSPECTOR

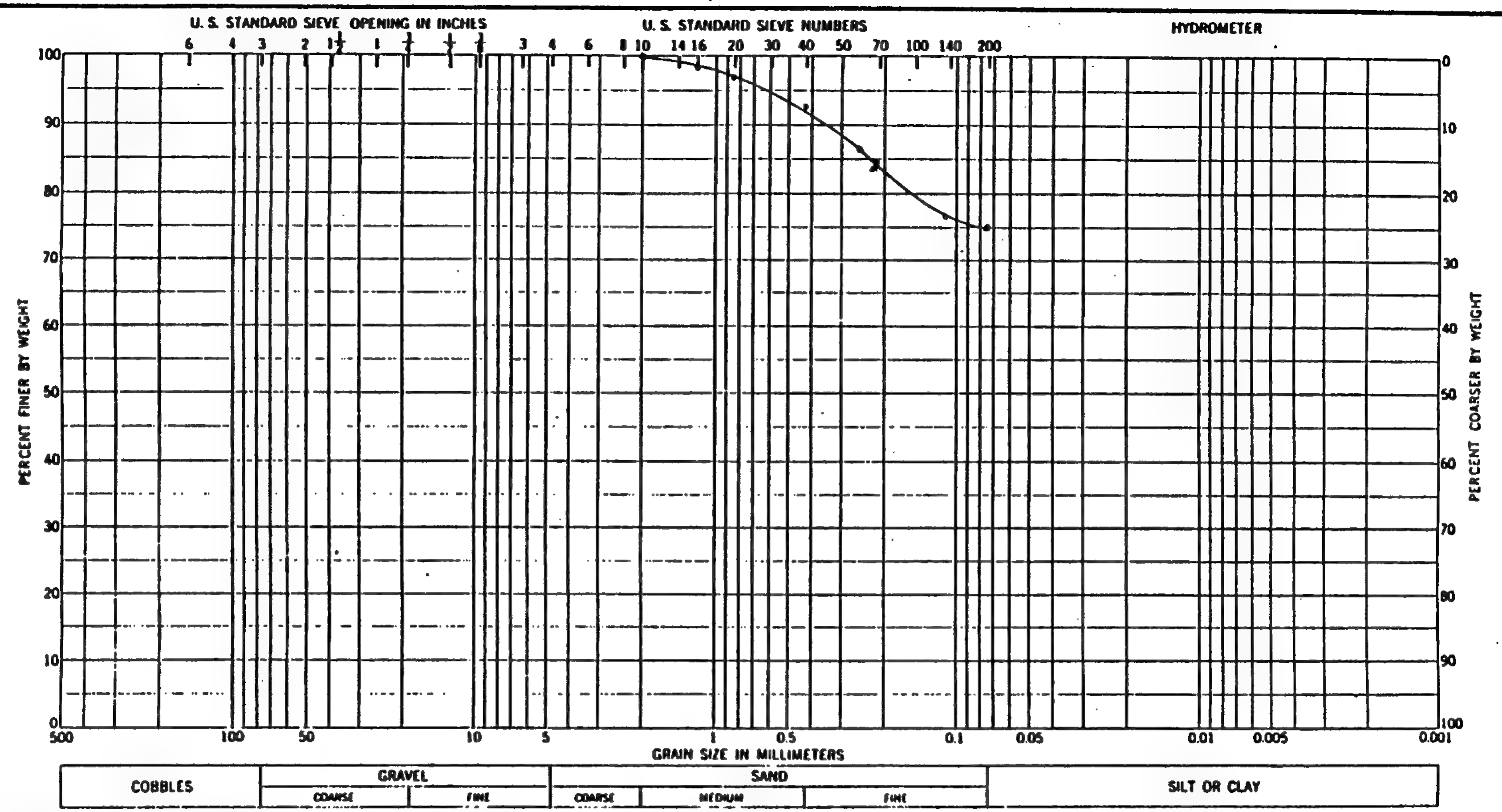
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Silty clay sand feces - few sand pockets 1.1 ft. (>.01), scattered shells			Sample 0 - 5 ft.
	5					
	7.4		Grey firm silt			Sample 7.4 - 10 ft.
	10					
	10.7		Grey silty clay, shell layer 12.1 Interbedded organic layers 12.65 to 12.83			
	12.2		Firm clay, scattered shells			Sample 12.2 - 15.0 ft.
	15					Sample 15 - 20 ft. Sand lenses in sample
	19.7		19.7 to 19.8 fine sand pockets			

PROJECT Delaware River Comprehensive Study HOLE NO. DRV-14



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRV - 14
Elev or Depth 0 - 5'
Classification Silty, Clayey Sand (SM-SC)
Nat w %
LL
PL
PI
Project Delaware River Tributaries
Area
Boring No. DRV - 14
Date 8 - 9 - 91
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRI-14
Silt
MH
62.7
29.1
33.6
Project Delaware River Vibracores
Area
Boring No. DRI-14
Date 8-9-91
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-14	12.2 - 15	Clay CL		34.6	21.0	13.6

Project: Delaware River Vibracores

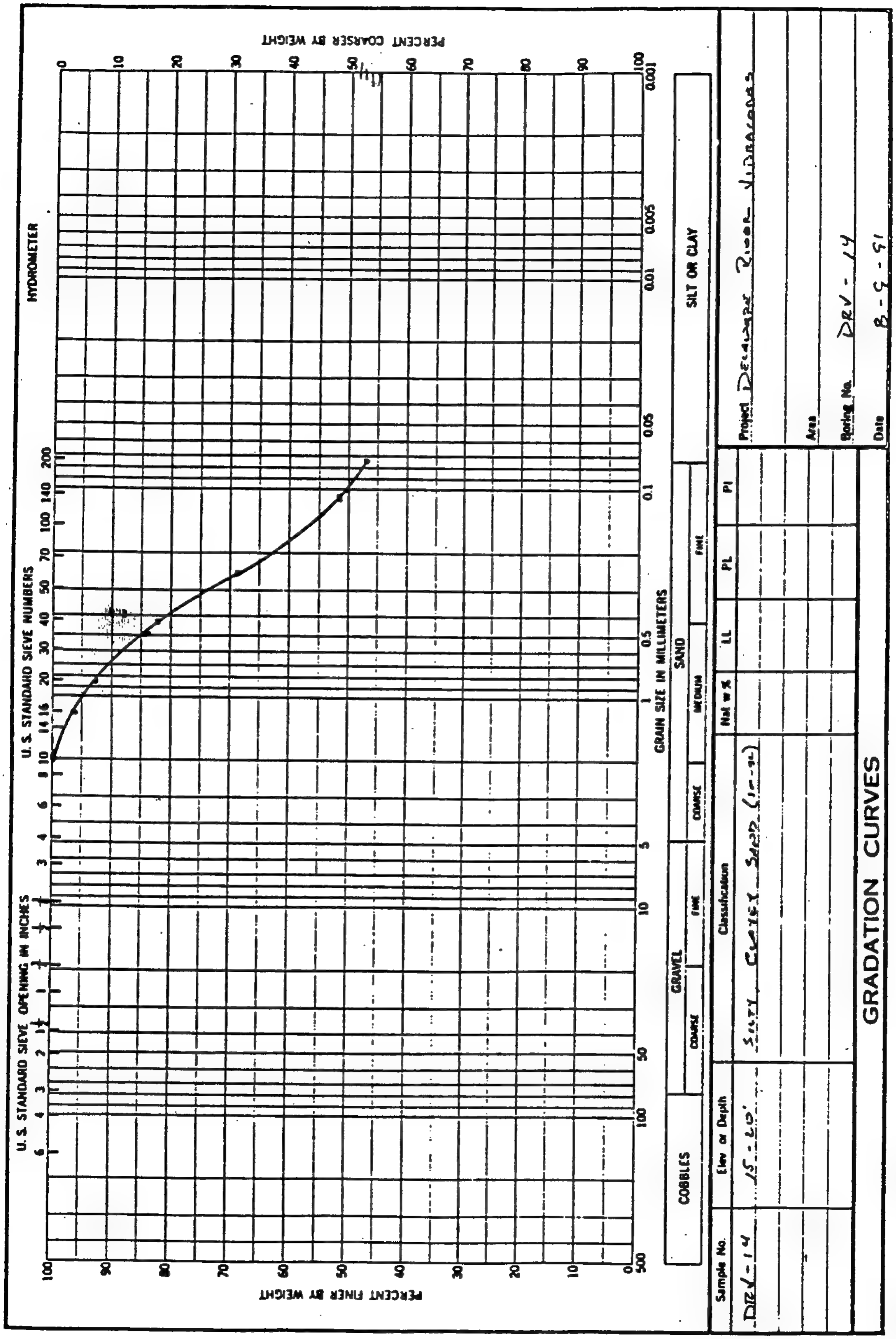
Area:

Boring No.: DRV - 14

Date: 8 - 9 - 91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

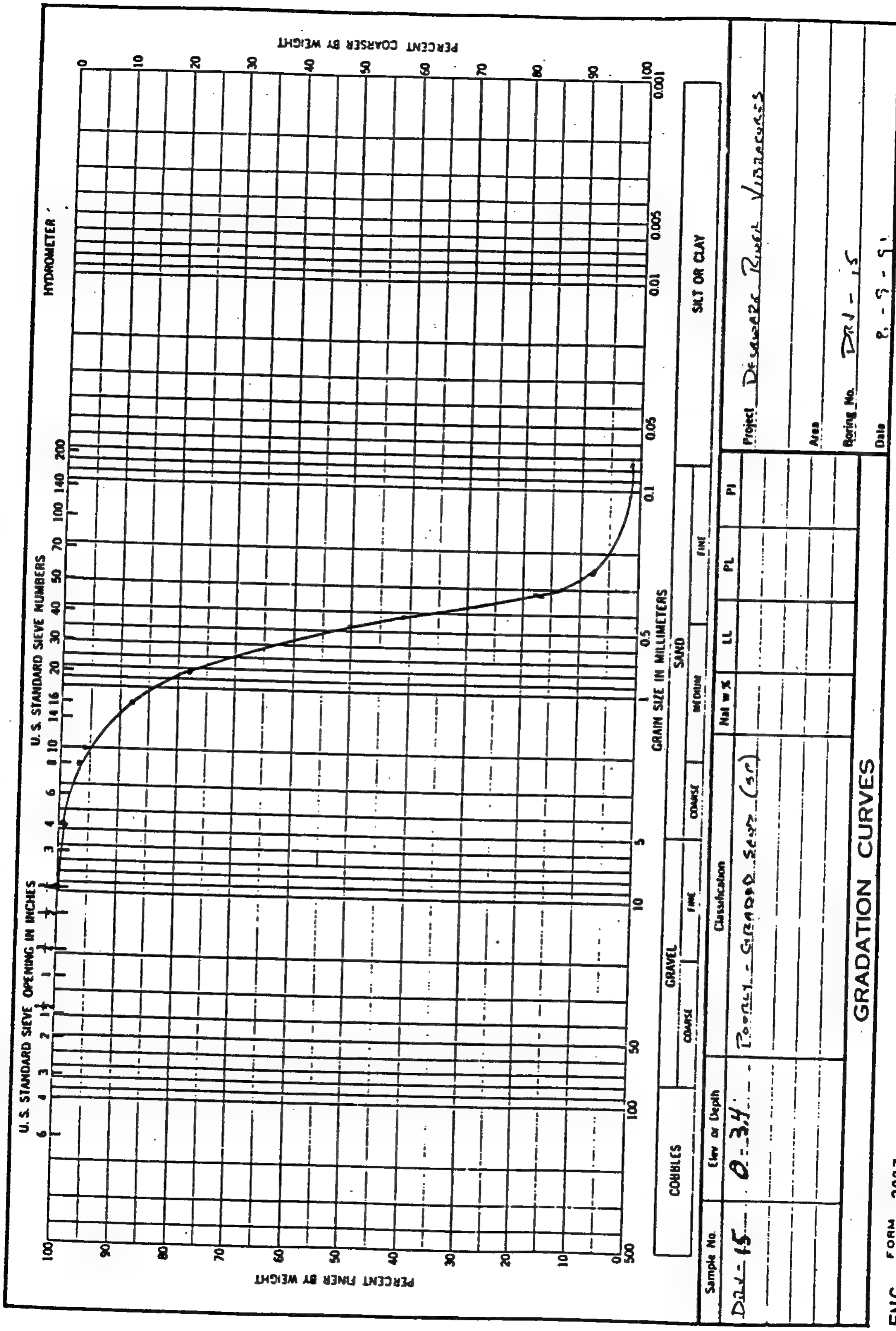

U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-14
15-20'
Silty Clayey Sand
Project Delaware River
Area
Boring No. DRV-14
Date 8-5-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Hole No. DRV-15

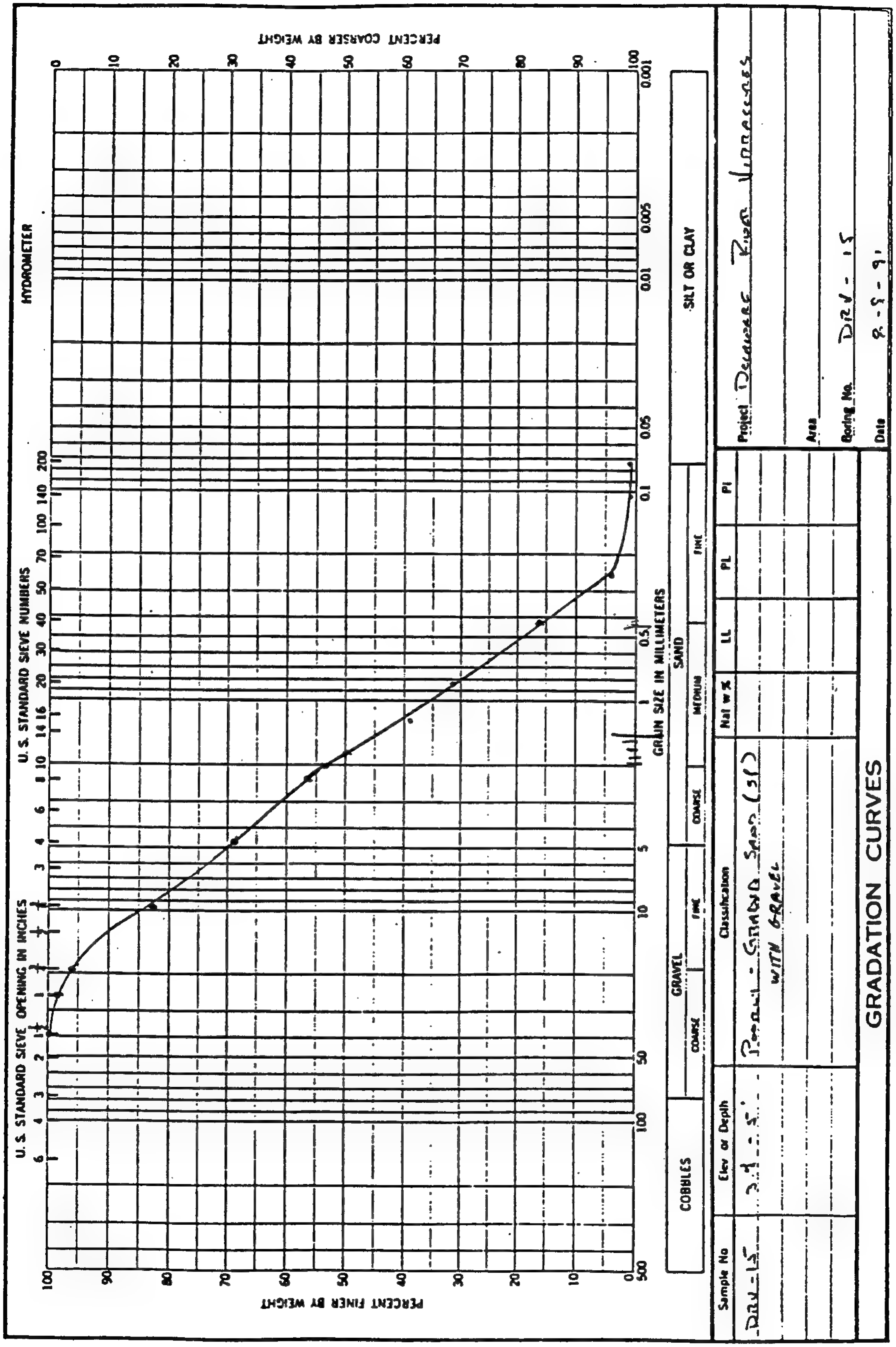
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

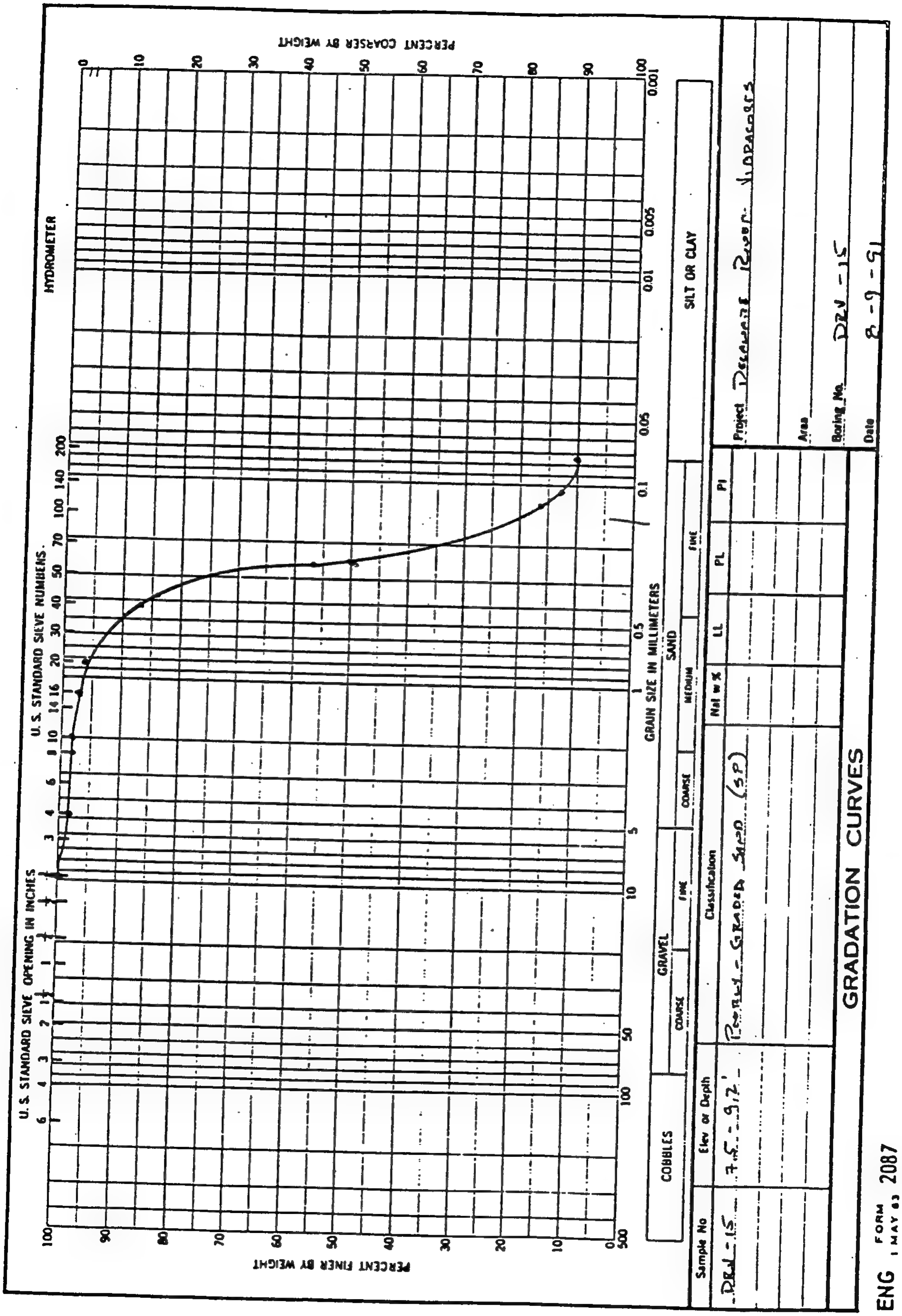
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 17' 28.98" 75° 22' 18.93"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchert-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-15	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/29/91 : COMPLETED 07/29/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -46.1 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 16.5 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0–3.4		Coarse to fine sand SP			Sample 0 - 3.4 ft.
	3.4–6.15		Brown fine to medium gravel gravelly coarse to fine brown sand sand SP Black silt with gravel			Sample 3.4 - 5.0 ft.
	6.15–7.5		Coarse to fine gravel with scattered cobbles -rounders brown sand at bottom SP			
	7.5–10.5		Very dense brown, orange interbedded sand SP White and dark brown marbled silt sand			Sample 7.5 - 9.2 ft.
	10.5–10.8		White sandy silt SM-SC			
	10.8–12.8		Orange sand silt with dark brown pods SP			Sample 10.8 - 14 ft.
	12.8–15		White silty sand with dark brown pods SP			
	15–16		Orange sandy silt SM-SC			Bottom of recovery

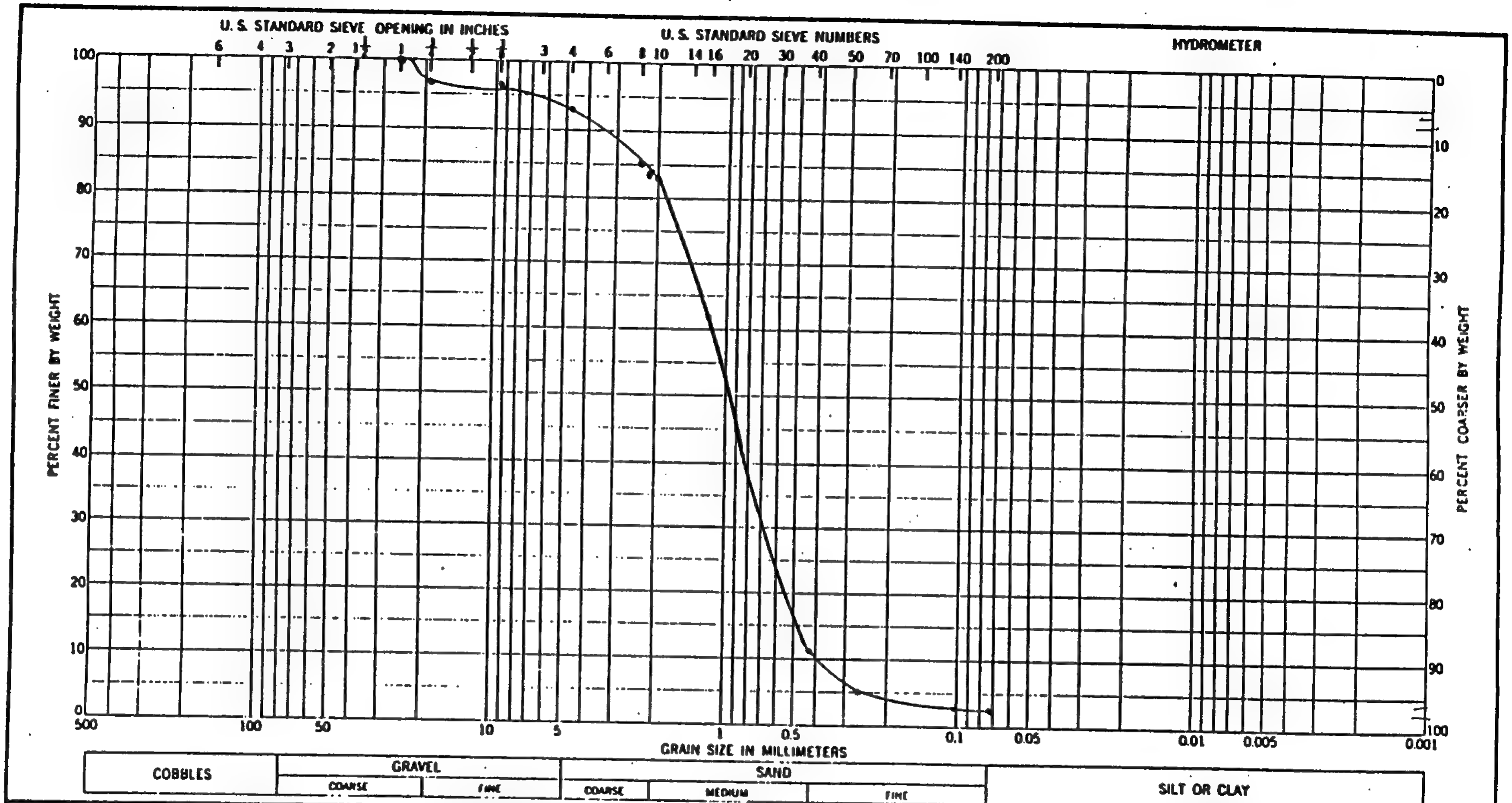


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-15
0-3.4'
Poorly-graded sand (SP)
Project Delaware River Vibracores
Area
Boring No. DRV-15
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


HYDROMETER
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-15
7.5 - 9.2'
Poorly-Graded Sand (SP)
Project Delaware River Vibracores
Area
Boring No. DRV-15
Date 8-9-91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-15	10.8-14'	Poorly-Graded Sand (SP)				

Project Delaware River Vibracores

Area

Boring No. DRV-15

Date 8-9-91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

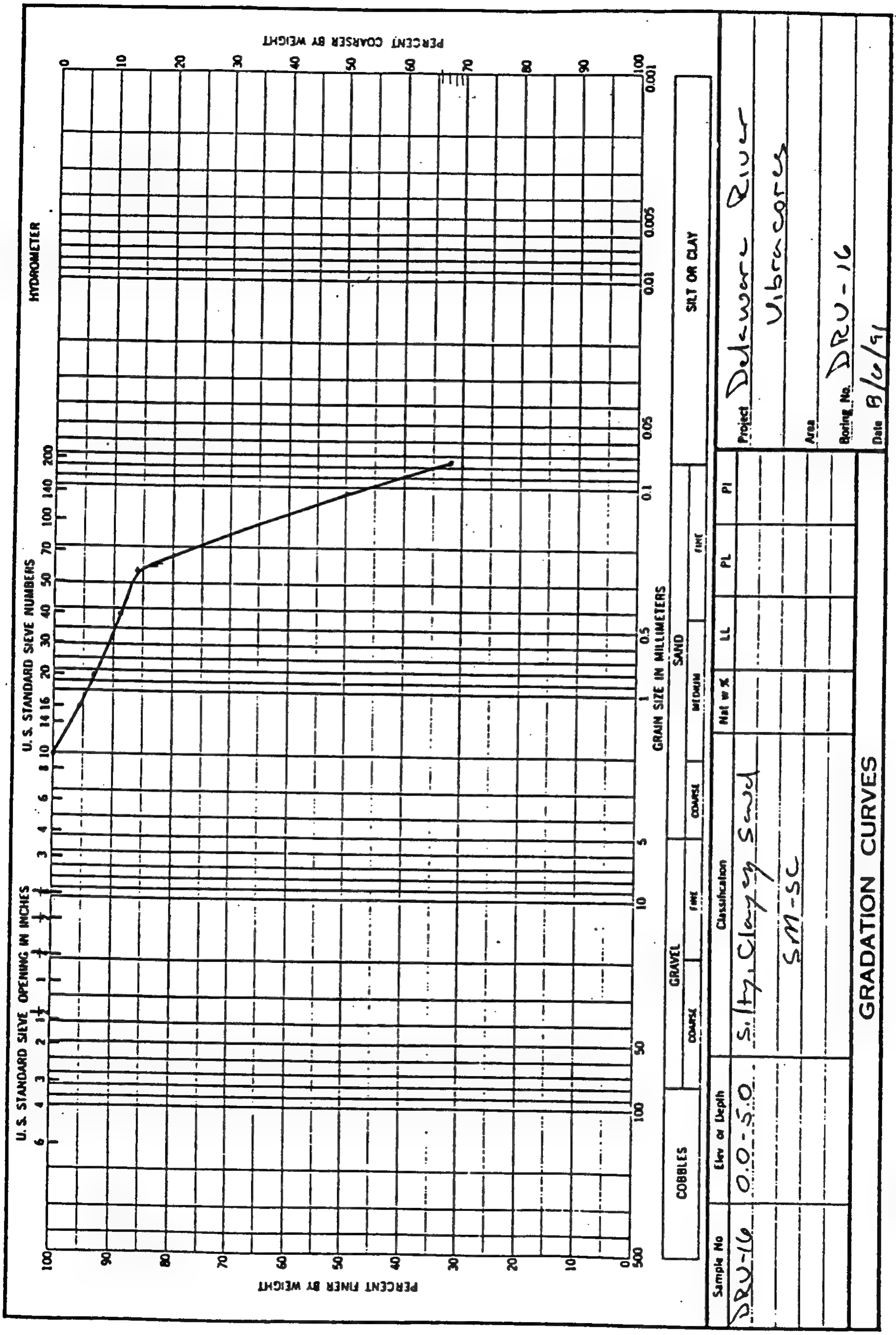
Hole No. DRV-16

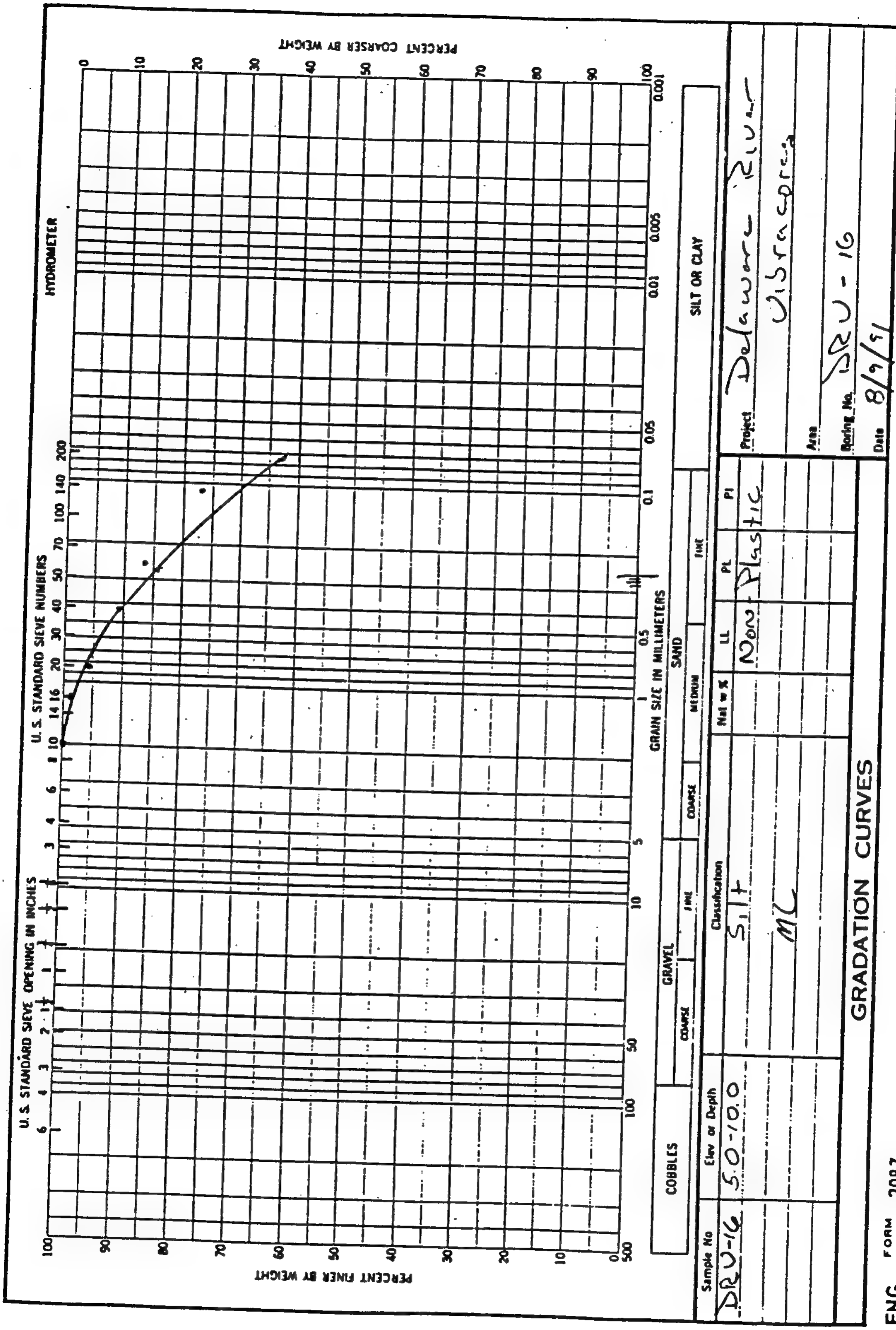
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

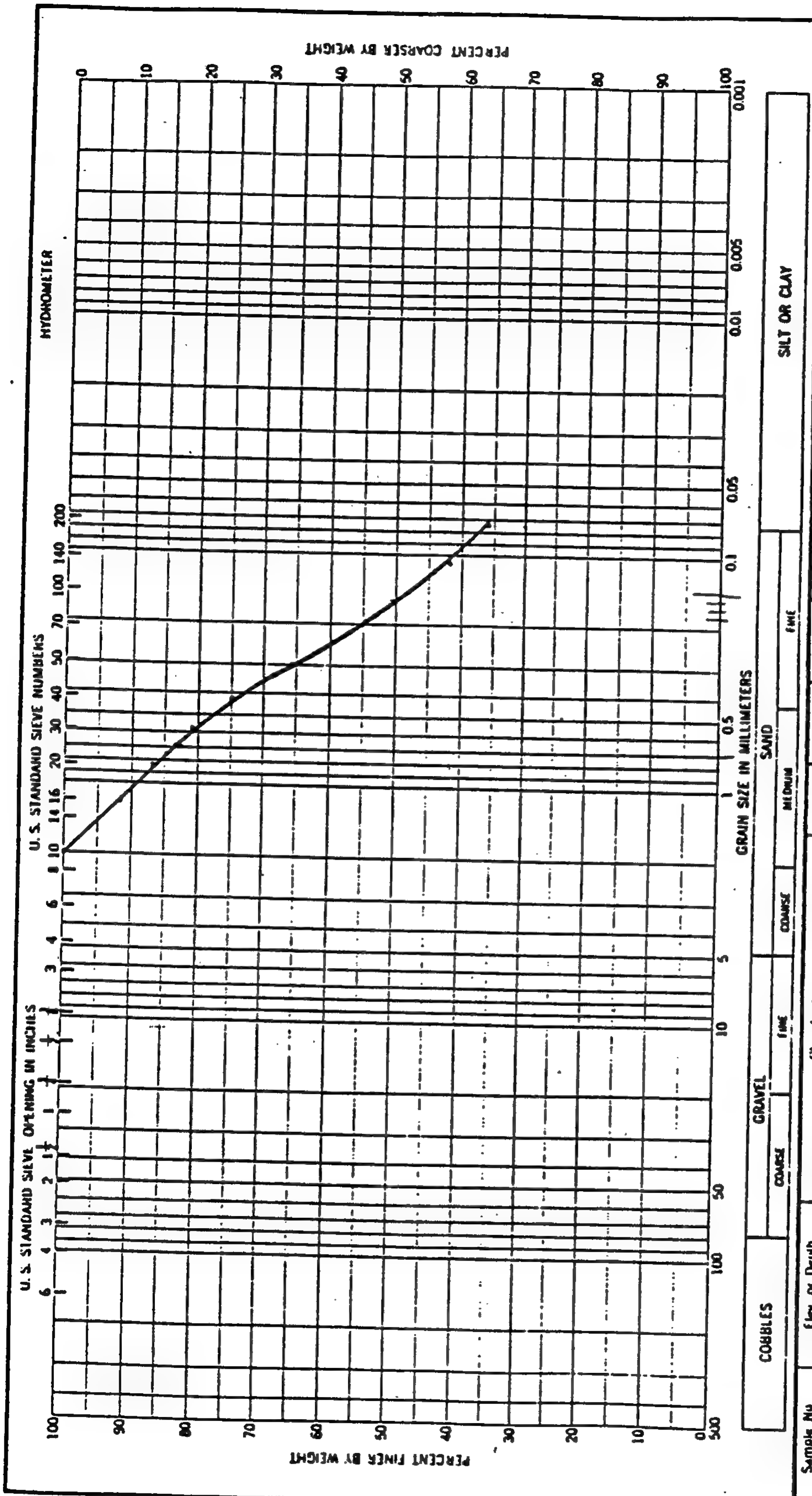
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 15' 5" 75° 20' 1.19"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-16	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
	15. ELEVATION GROUND WATER NA
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	16. DATE HOLE : STARTED 07/19/91 : COMPLETED 07/19/91
7. THICKNESS OF OVERBURDEN NA	17. ELEVATION TOP OF HOLE -35.5 ft. NGVD
8. DEPTH DRILLED INTO ROCK NA	18. TOTAL CORE RECOVERY FOR BORING 19 ft.
9. TOTAL DEPTH OF HOLE 20 ft.	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	1		Black gritty clay with fine sand lenses at .6 to .9 ft., 1.4 ft., 1.9 ft. and medium to fine sand at 2.3 to 2.4			
	2.4		Grey (dark) sandy silt grading finer downward			Sample 0 - 5 ft. Sand lenses in samples
	5		Sand at 5.3, 6.0, 7.05, 8.0 to 8.2			Sample 5 - 10 ft.
	11		Sand shell layer at 11.6 to 16.8			
	12		Sandy silt 12.2			Sample 10 - 15 ft.
	15		Sandy silt 15.75 Sandy silt 15.90			Sample 15 - 19 ft.
	17		Sandy silt 17.05 to 17.3			
	19		Bottom of recovery			

PROJECT Delaware River Comprehensive Study — HOLE NO. DRV-16


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-16
0.0-5.0
Silty, Clayey Sand
SM-SC
Project Delaware River
Vibracores
Area
Boring No. DRU-16
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-16
Elev or Depth
5.0-10.0
Classification
Silt
ML
Nat w %
LL
PL
PI
Non-Plastic
Project
Delaware River
Area
Boring No.
DRV-16
Date
8/9/91
ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-16	10.0-15.0	Silty, clayey sand				
		SM-SC				

Project Delaware River Vibracores

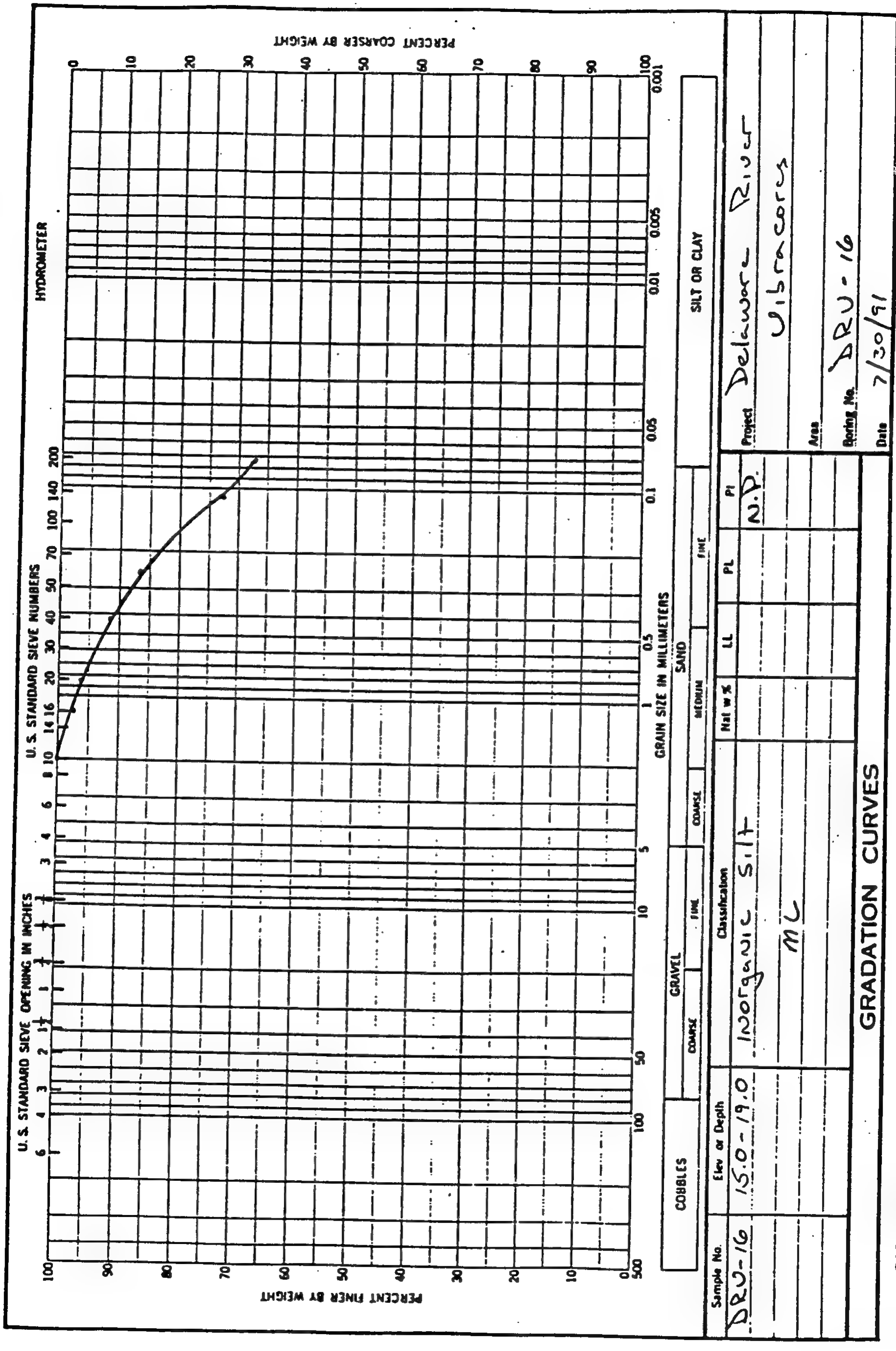
Area

Boring No. DRV-16

Date 7/29/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRU-16
Elev or Depth 15.0-19.0
Classification Inorganic Silt ML
Nat w %
LL
PL
PI N.P.
Project Delaware River Vibracores
Area
Boring No. DRU-16
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Hole No. DRV-17

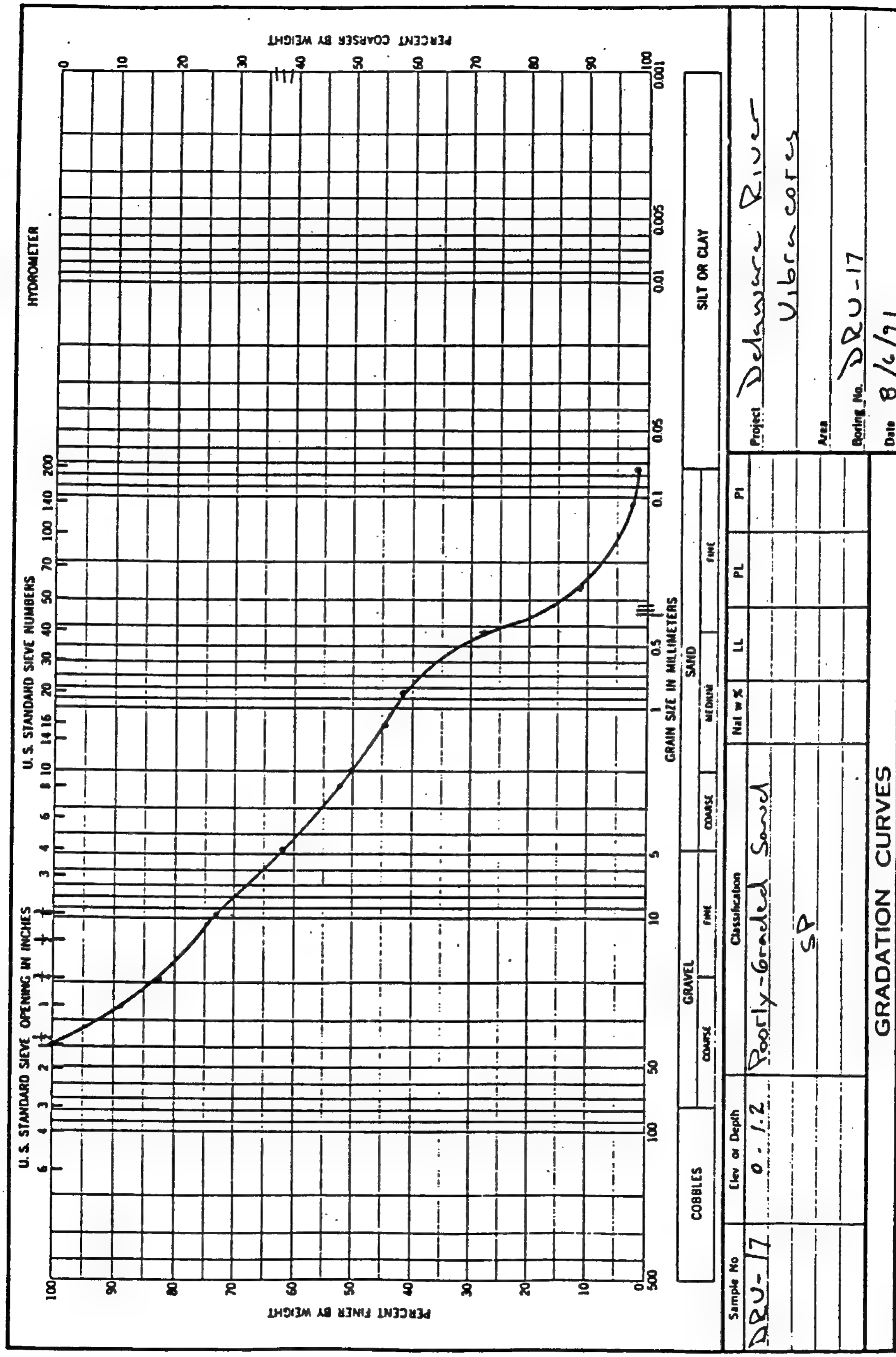
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

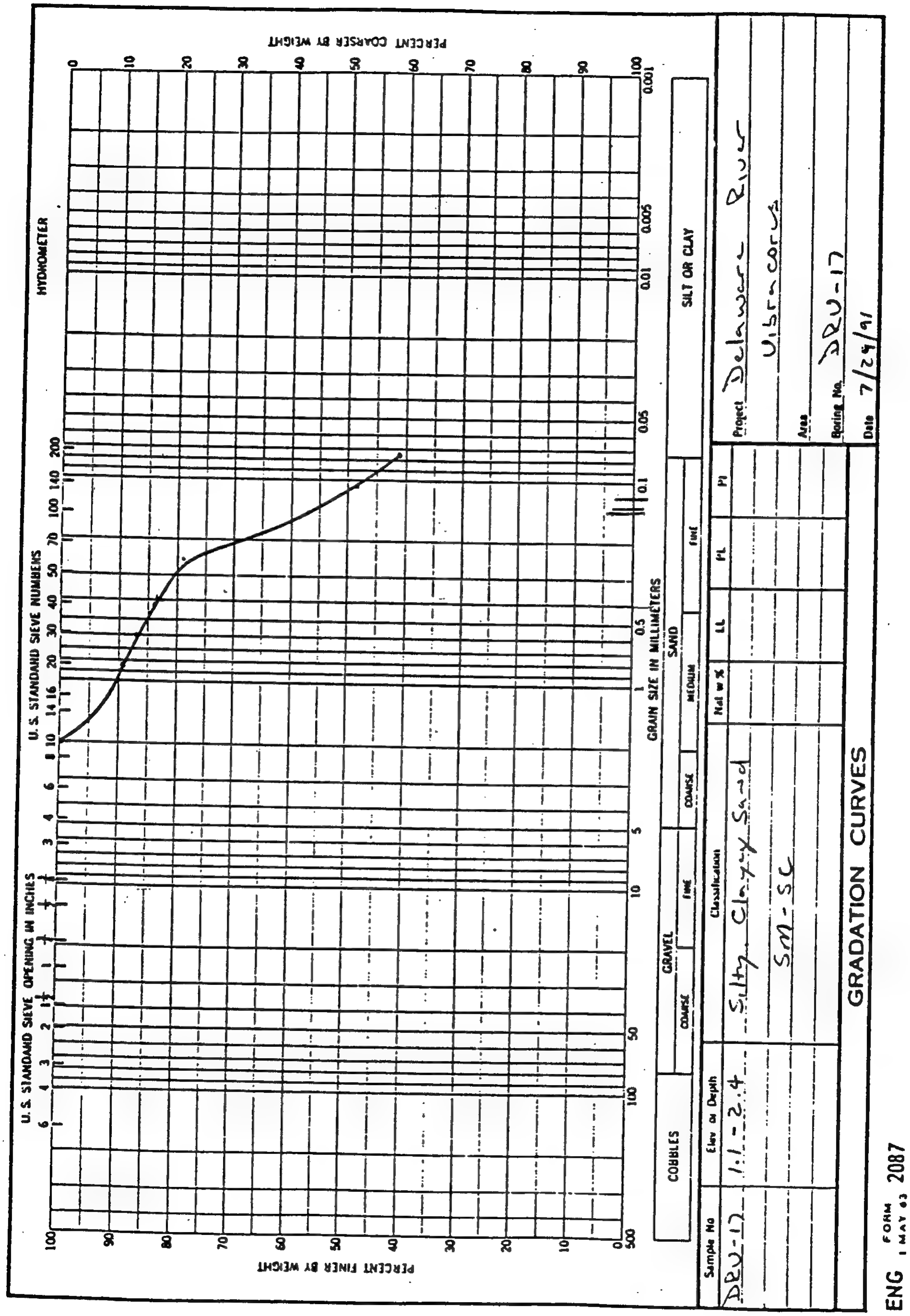
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 13' 02.67" 75° 17' 40.30"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-17	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/19/91 : COMPLETED 07/19/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -46.5 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 10 ft.
	19. SIGNATURE OF INSPECTOR

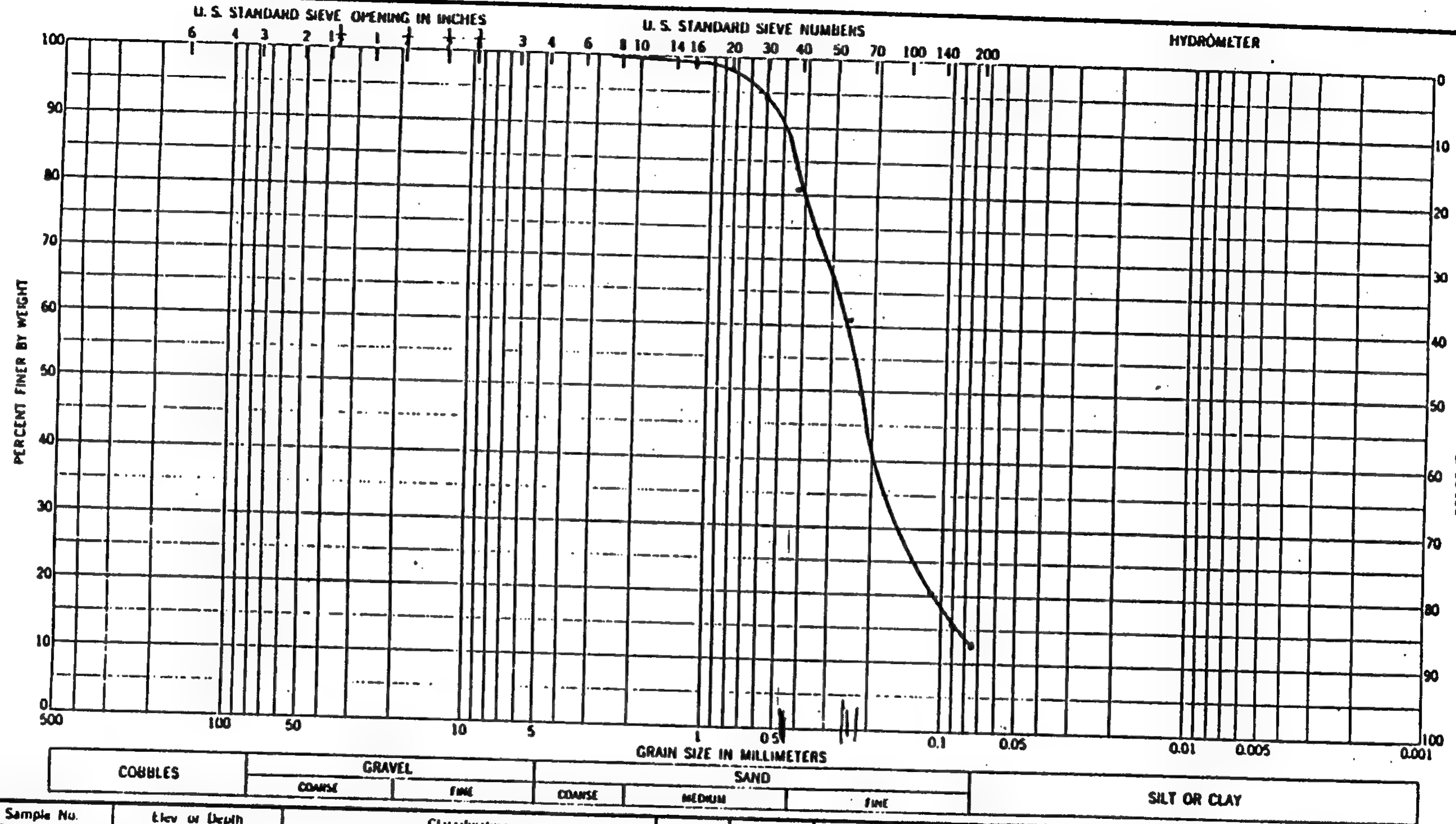
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Brown medium to fine sand SP			20 ft. penetration 10 ft. recovery, rest of sample fell out. Oyster shells destroyed capture cone
	1.2		Grey silt SM-SC			Sample 0 - 1.2 ft. Sample 1.1 - 2.4 ft.
	2.4		Grey fine sand, some shells SM-SC			Sample 2.4 - 3.7 ft.
	3.7		Grey clay or silt with sand and sand shell layer at 4.8 to 5.2, 5.3 to 5.7, 6 to 6.2, 6.5, 6.6 to 7.6 and 8.2 to 8.3 SM-SC			Sample 3.7 - 10 ft. Sand in sample
	10.5		Rest of sample fell out.		10.5	Bottom of recovery

Depth scale: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-17


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-17
Elev or Depth
0 - 1.2
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-17
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-17
1.1-2.4
Silty Clayey Sand
SM-SC
Project Delaware River
Vibracores
Area
Boring No. DRU-17
Date 7/29/91
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-17	2.4-3.7	Silty, Clayey Sand				
		SM-SC				

Project Delaware River Vibracores

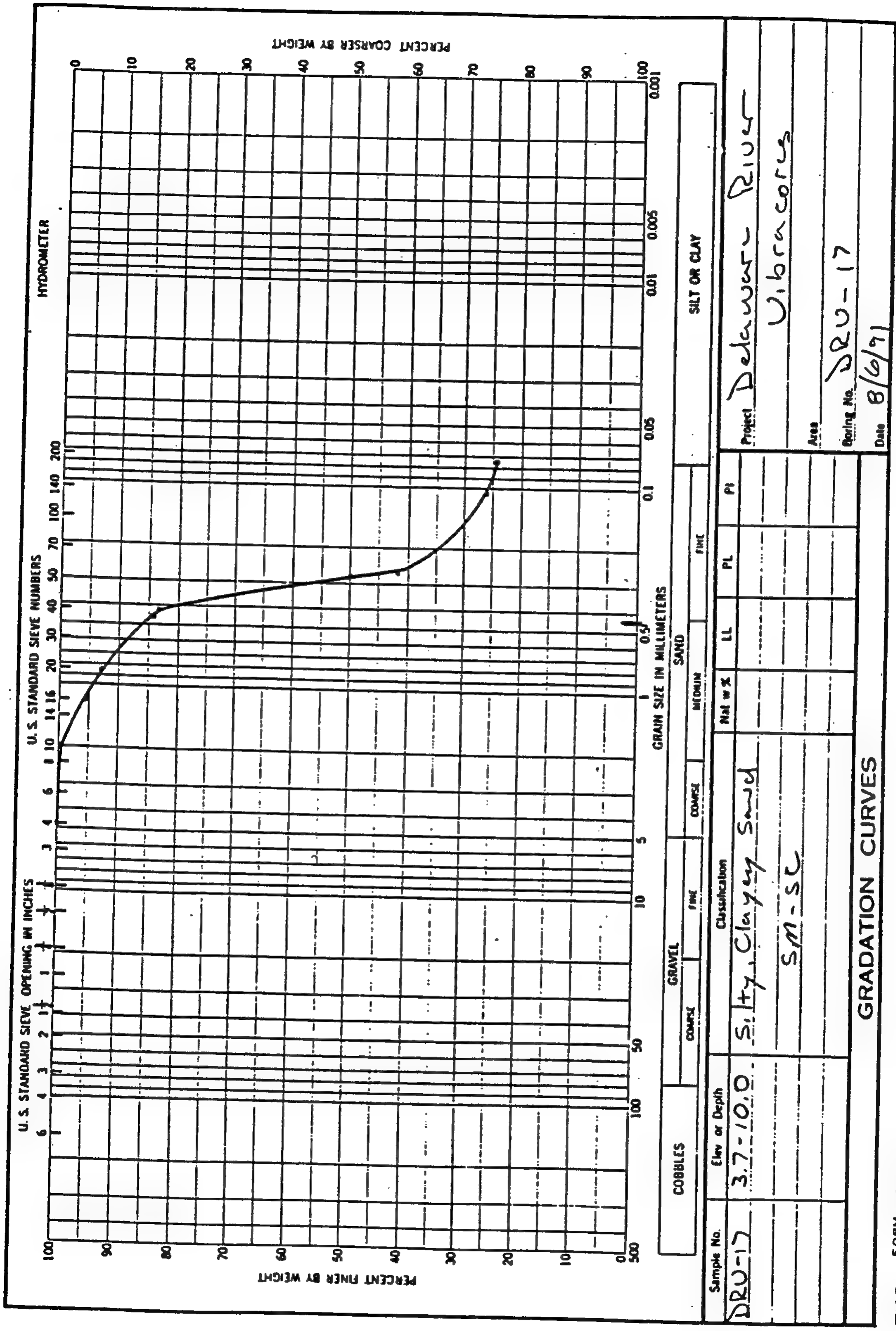
Area

Boring No. DRU-17

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRU-17
Elev or Depth
3.7-10.0
Classification
Silty, Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-17
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

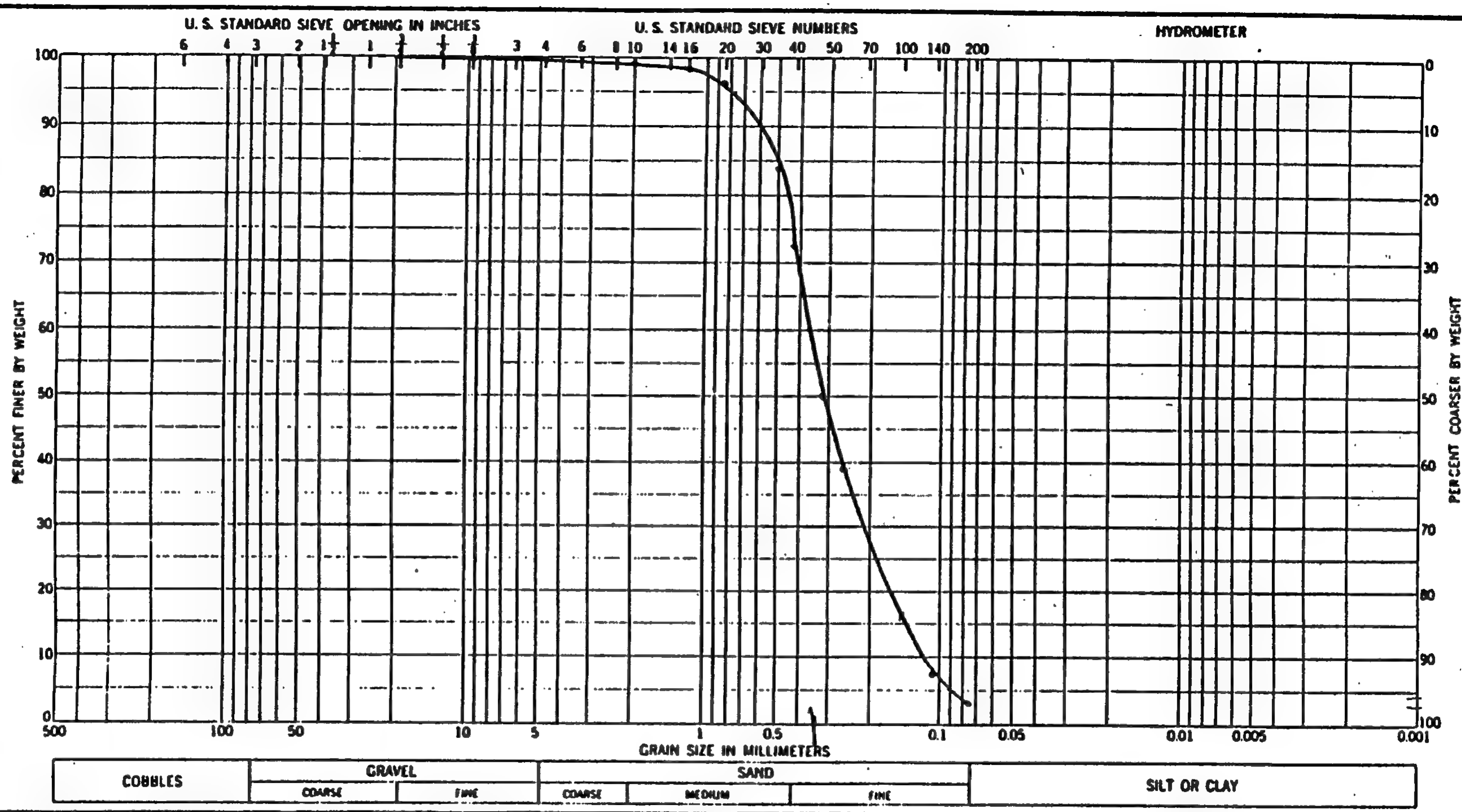
Hole No. DRV-18

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Delaware River Comprehensive Study		10. SIZE AND TYPE OF BIT Vibracore	
2. LOCATION (Coordinates or Station) 39° 10' 35.08" 75° 16' 0.16"		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY Buchart-Horn, Inc.		12. MANUFACTURER'S DESIGNATION OF DRILL NA	
4. HOLE NO. (As shown on drawing title and file number)	DRV-18	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED :	: UNDISTURBED :
5. NAME OF DRILLER Ocean Survey, Inc.		14. TOTAL NUMBER CORE BOXES NA	
		15. ELEVATION GROUND WATER NA	
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.		16. DATE HOLE : STARTED : 07/18/91	: COMPLETED : 07/18/91
7. THICKNESS OF OVERBURDEN NA		17. ELEVATION TOP OF HOLE -43.2 ft. NGVD	
8. DEPTH DRILLED INTO ROCK NA		18. TOTAL CORE RECOVERY FOR BORING 12 ft.	
9. TOTAL DEPTH OF HOLE 14.5 ft.		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Fine sand grey			Sample 0 - 4.1 ft.
	1.5		Brown fine sand			
	2		Black fine sand			
	4.2		Black fine sand			
	5.2		Sandy gravel			Sample 5.2 - 9.1 ft.
	9.1		Grey fine silty sand			Sample 9.1 - 10 ft.
	10.3		Grey coarse to fine sand			
	10.7		Grey silty fine sand with scattered gravel			Sample 10.7 - 11.7 ft.
	11.7		Silty gravel			Bottom of recovery

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-18



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-18	0.0-4.1	Poorly-Graded Sand SP				

GRADATION CURVES

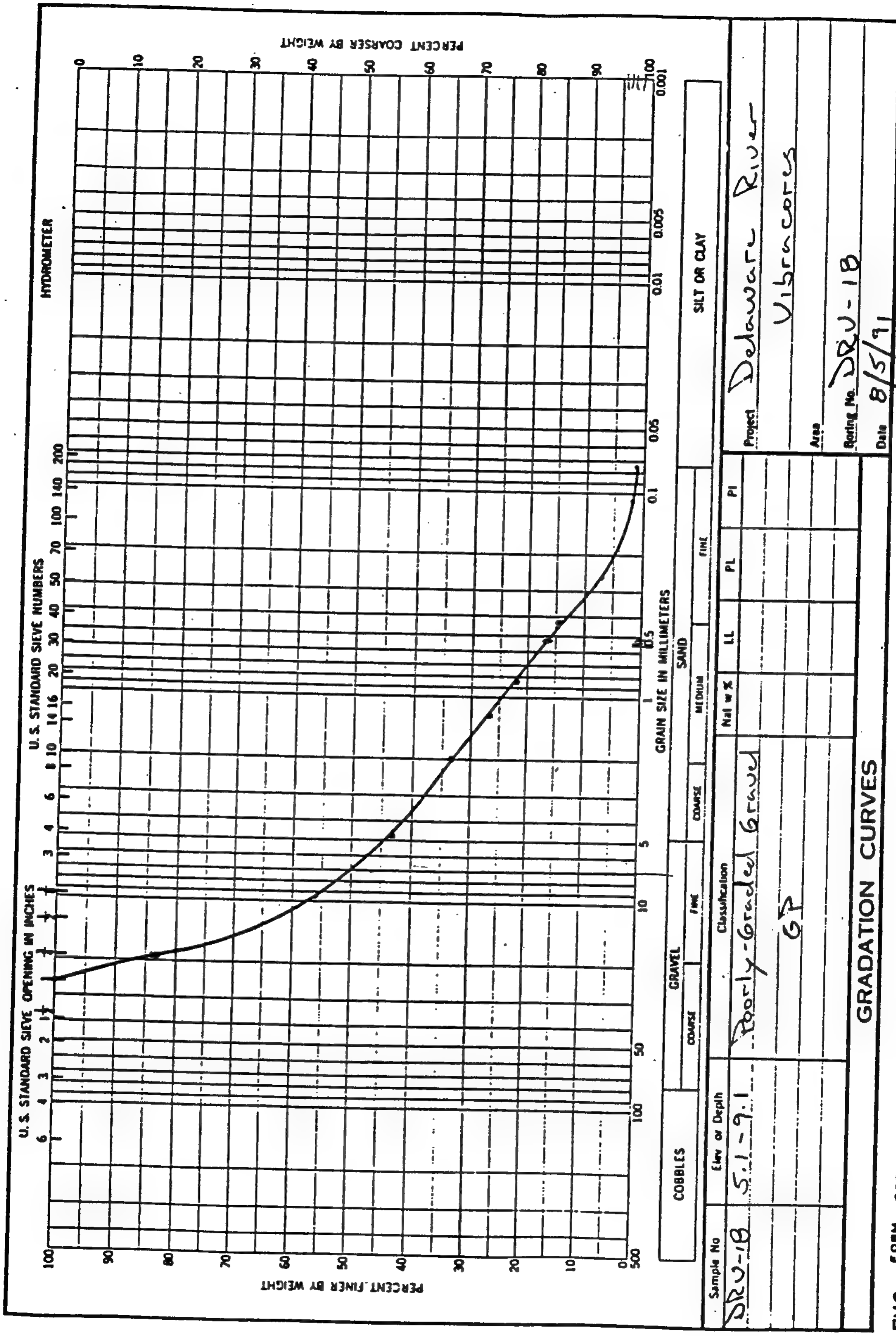
Project Delaware River Vibracores

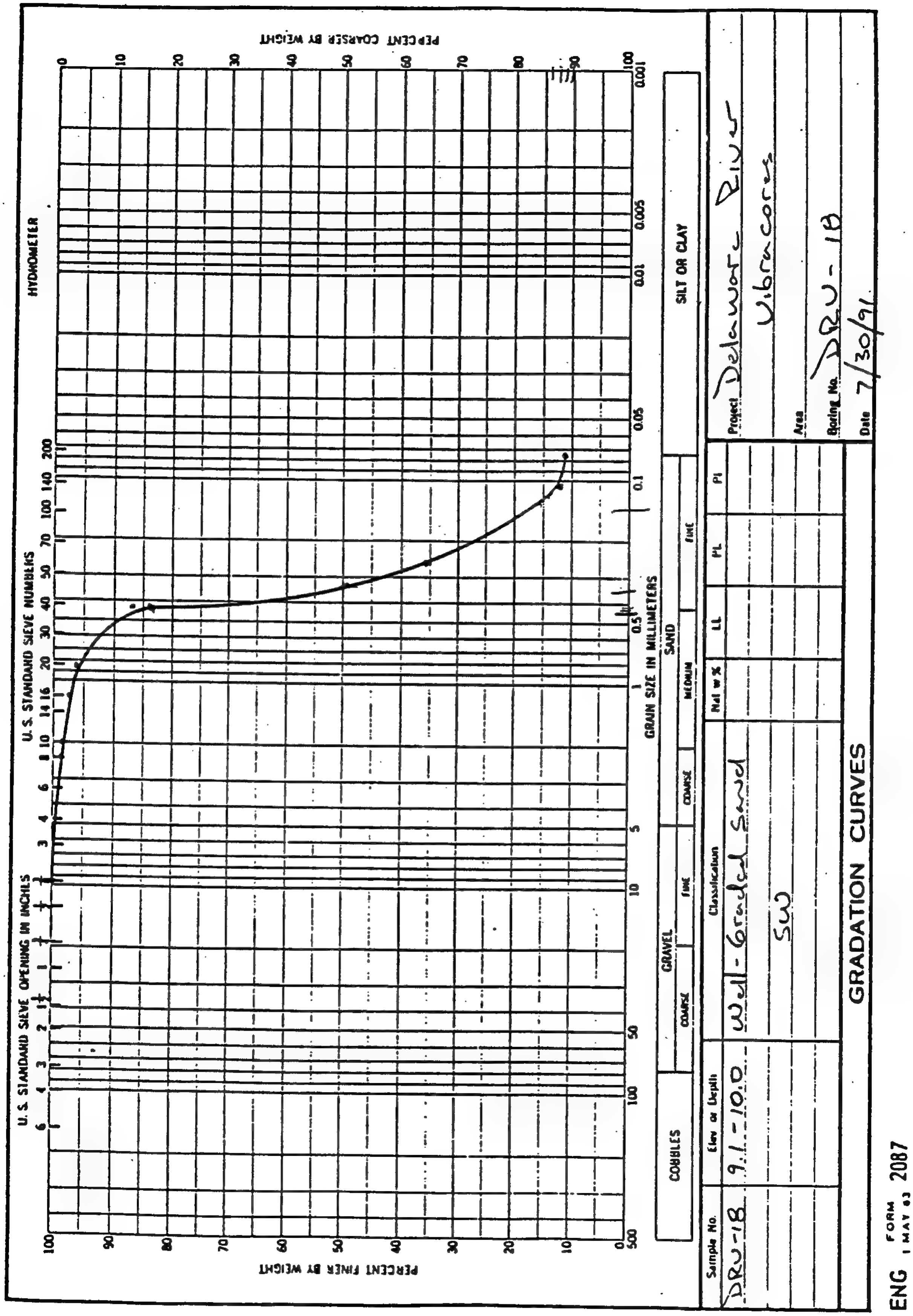
Area

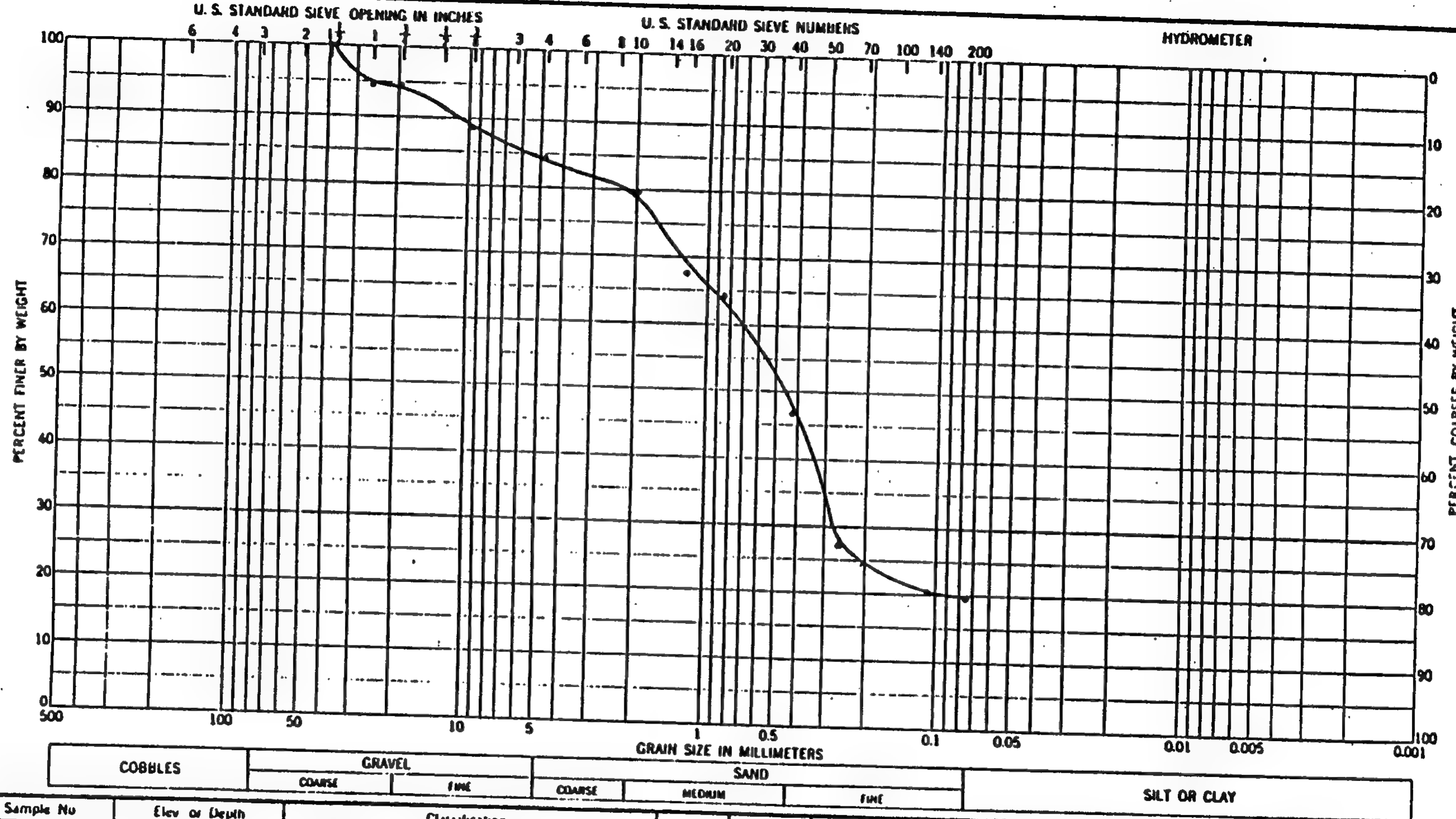
Boring No. DRV-18

Date 8/6/91

ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-18
Elev or Depth
5.1-9.1
Classification
Poorly-Graded Gravel
GP
Nat w %
LL
PL
PI
Project
Delaware River
Vibracores
Area
Boring No.
DRV-18
Date
8/5/91
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-1B
9.1-10.0
Well-Graded Sand
SW
Project Delaware River
Vibracores
Area
Boring No. DRV-1B
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-18	10.7-11.7	Silty, Clayey Sand				
		SM-SC				

Project Delaware River Vibracores

Area

Boring No. DRU-18

Date 7/31/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Hole No. DRV-19

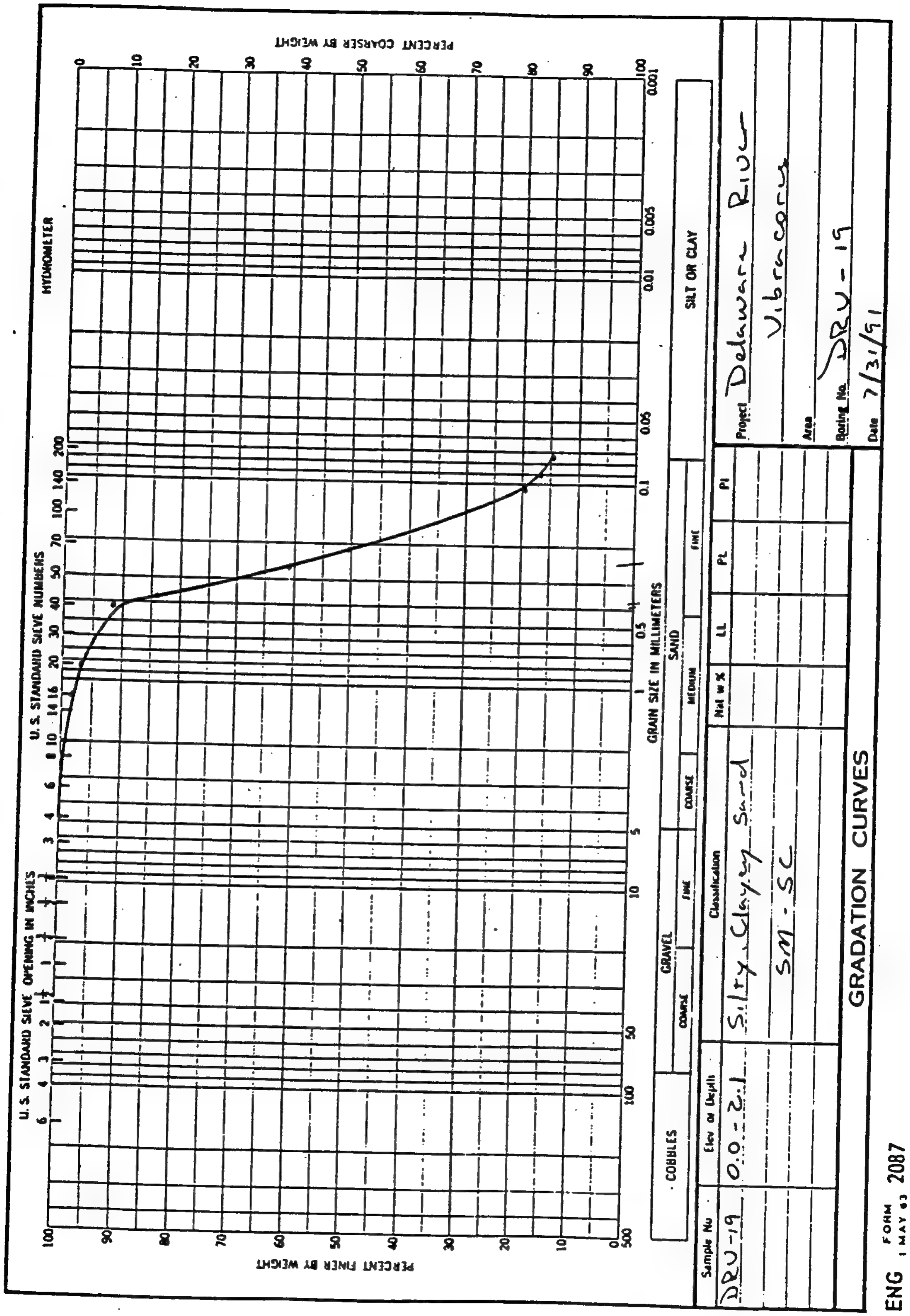
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT
Delaware River Comprehensive Study
2. LOCATION (Coordinates or Station)
39° 08' 47.16" 75° 14' 30.27"
3. DRILLING AGENCY
Buchart-Horn, Inc.
4. HOLE NO. (As shown on drawing title and file number) DRV-19
5. NAME OF DRILLER Ocean Survey, Inc.
6. DIRECTION OF HOLE
VERTICAL INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN NA
8. DEPTH DRILLED INTO ROCK NA
9. TOTAL DEPTH OF HOLE 20 ft.

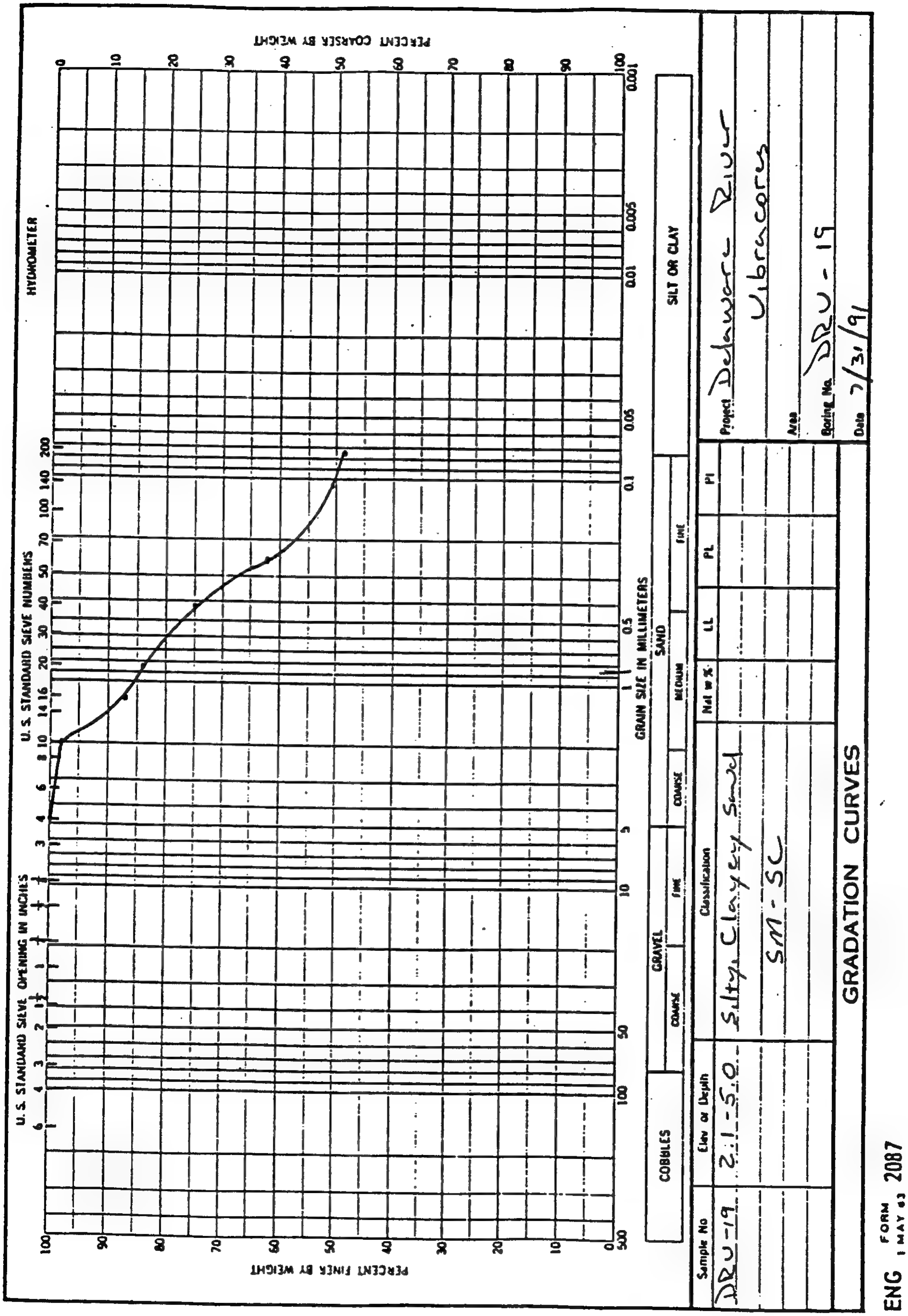
10. SIZE AND TYPE OF BIT Vibracore
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
NA
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
14. TOTAL NUMBER CORE BOXES NA
15. ELEVATION GROUND WATER NA
16. DATE HOLE : STARTED 07/18/91 : COMPLETED 07/18/91
17. ELEVATION TOP OF HOLE -45.5 ft. NGVD
18. TOTAL CORE RECOVERY FOR BORING 20 ft.
19. SIGNATURE OF INSPECTOR

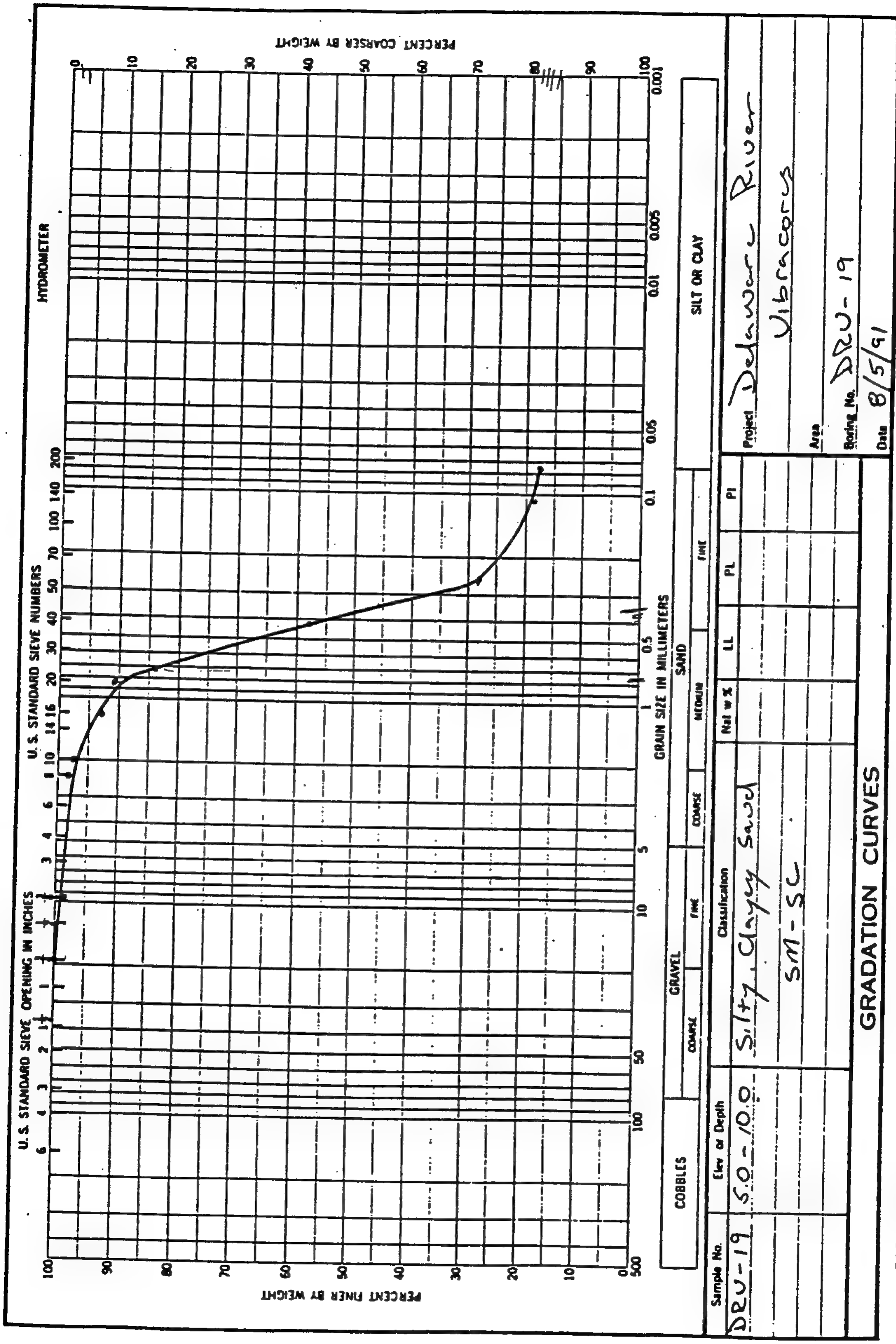
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–2.1		SM-SC Grey silty sand with shell fragments			Recovery - 20 of 20 ft. Sample 0 - 2.1 ft.
	2.1–11.1		Grey clay with scattered shells sand lenses at 3.7, 5.0, 7.5; 5.7, 5.0, 6.5 to 6.8, 8 to 8.5; 7.5, 8.8 and 9.5 shells in fine grey sandy layers SM-SC SM-SC			Sample 2.1 - 5.0 ft. Sand lenses in sample Sample 5 - 10.0 ft.
	11.1–15.7		Grey clayey sand with shell layers at 11.5, 13 to 13.8, 14.1 to 14.2, and 14.4 to 14.6 SM-SC			Sample 11 - 15 ft.
	15.7–16.7		Clayey coarse to fine gravel GP			Sample 15.7 - 16.7 ft.
	16.7–18.9		Grey clay, sandy gravel-13.2 to 13.3 SM-SC			Sample 5 - 10 ft.
	18.9–20		Fine sandy coarse to fine gravel GP			Sample 15.7 - 16.7 ft.

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-19



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-19
Elev or Depth
0.0 - 2.1
Classification
Silty, Clayey Sand
SM - SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV - 19
Date 7/31/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No: DRU-19
Elev or Depth: 2.1-5.0
Classification: Silty, Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project: Delaware River Vibracores
Area
Boring No. DRU-19
Date 7/31/91
ENG FORM 1 MAY 63 2087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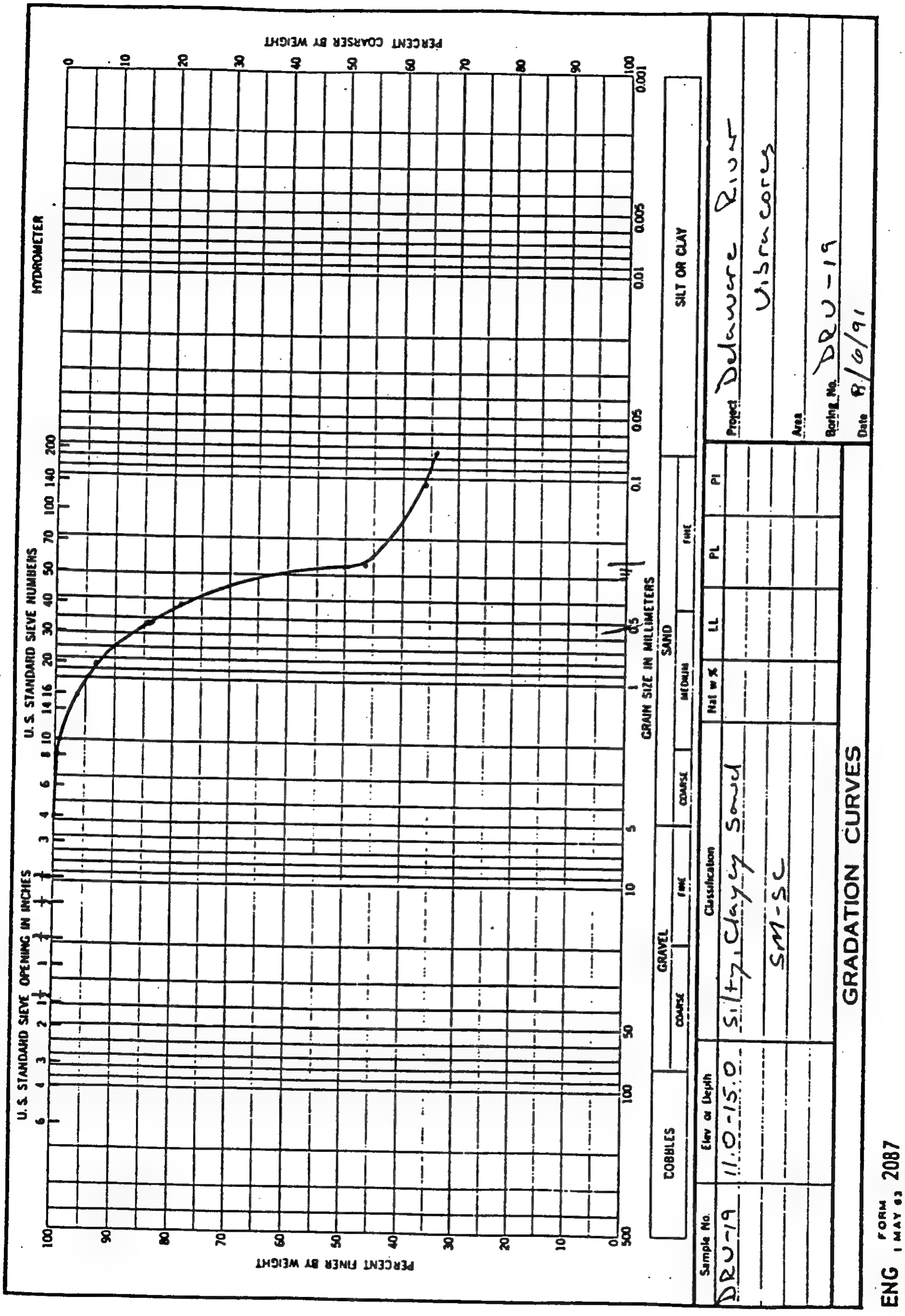
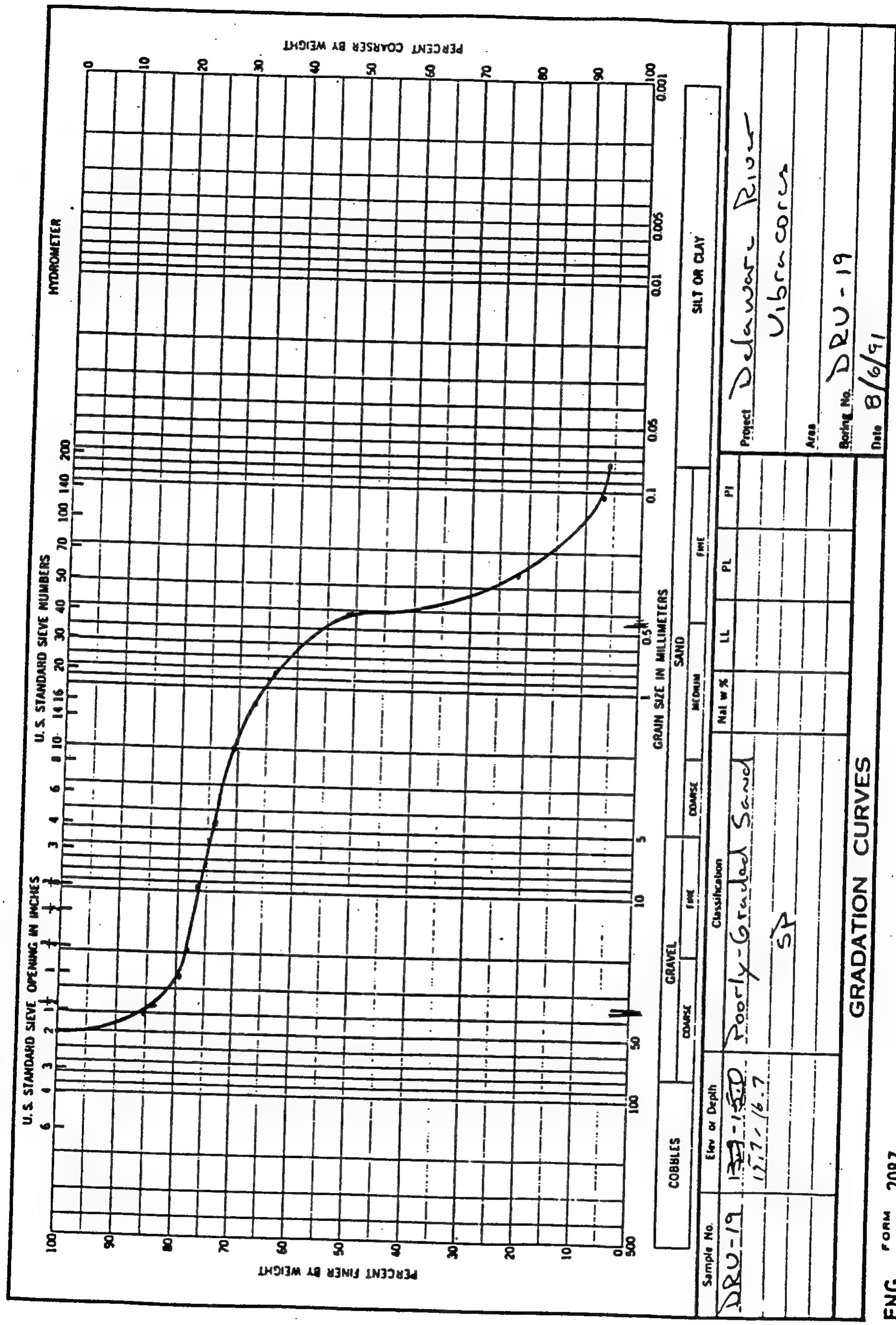
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-19
5.0-10.0
Silty Clayey Sand
SM-SC
Project Delaware River
Vibracores
Area
Boring No. DRU-19
Date 8/5/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRU-19
Elev or Depth 11.0-15.0
Classification Silty, Clayey Sand SM-SC
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRU-19
Date 8/6/91
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
COARSE
FINE
MEDIUM
Sample No.
DRV-19
Elev or Depth
15.7/16.7
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-19
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

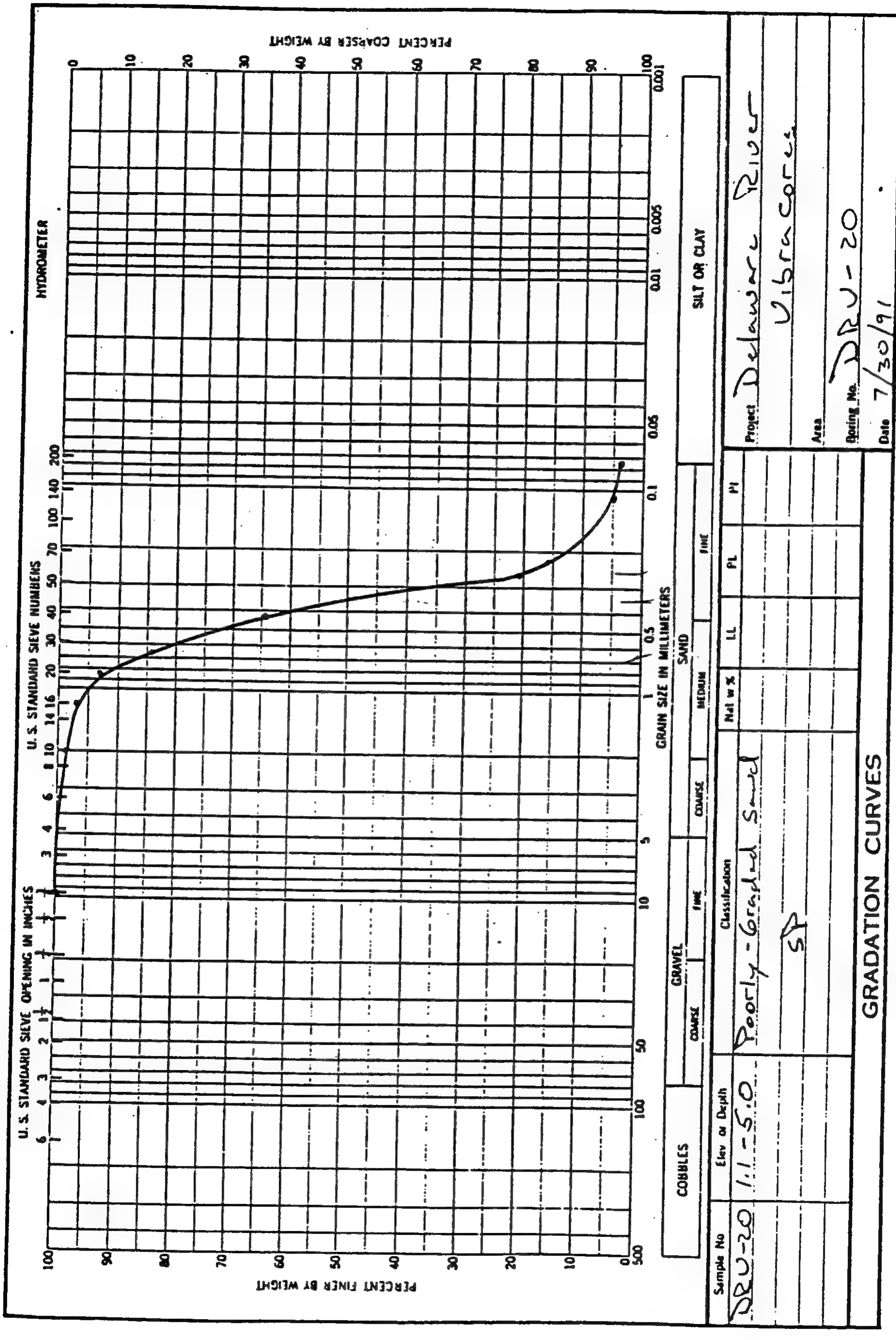
Hole No. DRV-20

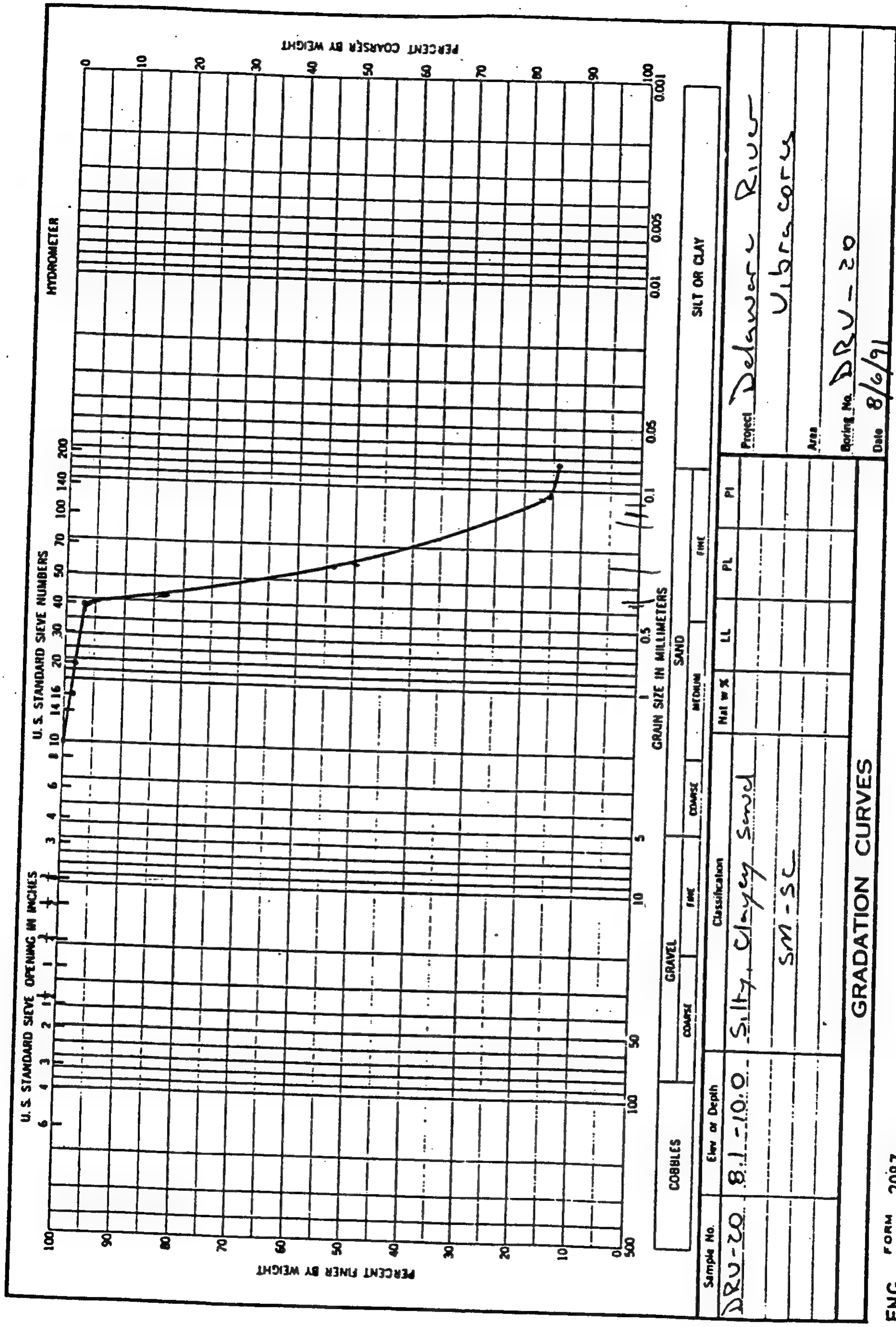
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

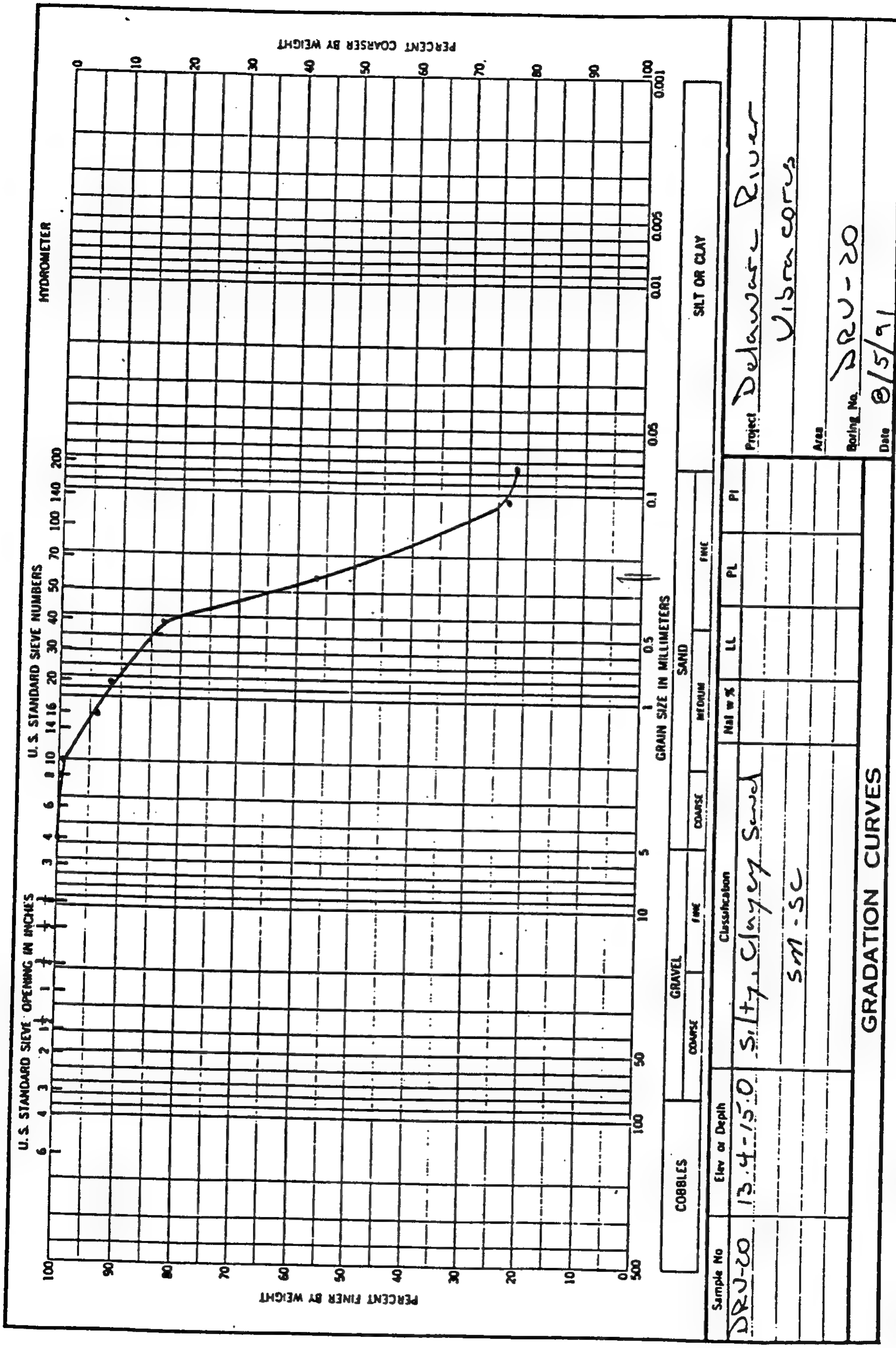
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 7' 8.45" 75° 13' 5.44"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-20	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/18/91 : COMPLETED 07/18/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -44.9 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 20 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Black sandy gravel-medium to fine gravel			
	1 .1		Light grey silt clay			
	1.1		Yellow fine sand with scattered gravel, red clay pod at 2.25 to 2.5, grey clay pockets (1") throughout			Sample 1.1 - 5.0 ft.
	4		No gravel below 4.2 ft.			
	8		Grey silty sand grading finer downward			Sample 8.1 - 10 ft.
	11.2		Red sandy silt			
	13.3		Brown clayey sand, fining downward, micaceous			Sample 13.4 - 15.0 ft.
	15.9		Fine clayey sand			Sample 15.9 - 20 ft.

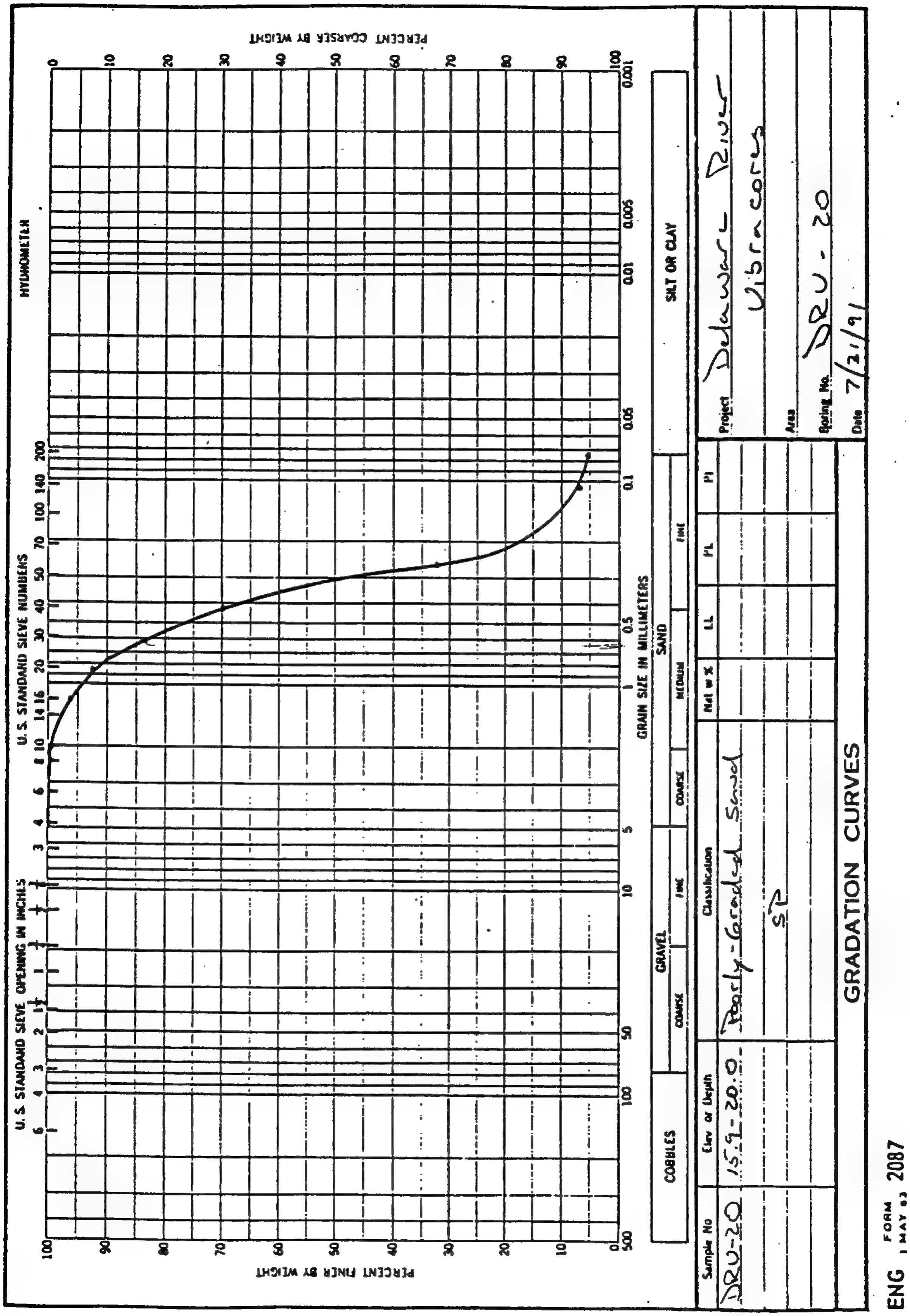
PROJECT Delaware River Comprehensive Study HOLE NO. DRV-20


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRV-20
Elev or Depth
1.1-5.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-20
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-20
8.1-10.0
Silty Clayey Sand
SM-SC
Project Delaware River
Vibracores
Area
Boring No. DRV-20
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-20
13.4-15.0
Silty, Clayey Sand
SM-SC
GRADATION CURVES
Project Delaware River Vibracores
Area
Boring No. DRU-20
Date 8/5/91
ENG FORM 1 MAY 63 2087

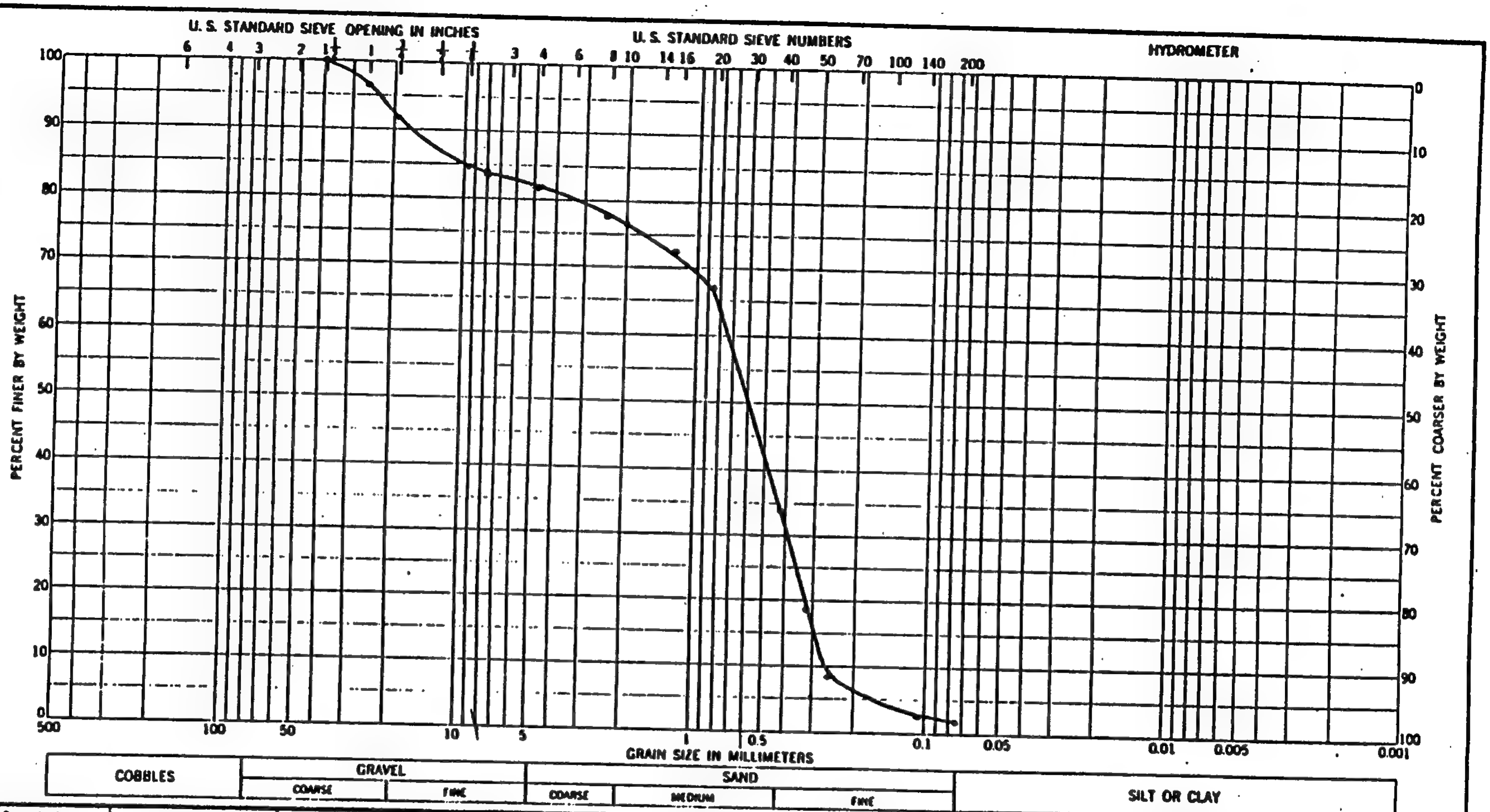

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-20
Elev or Depth
15.9-20.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-20
Date 7/31/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Hole No. DRV-21

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Delaware River Comprehensive Study		10. SIZE AND TYPE OF BIT Vibracore	
2. LOCATION (Coordinates or Station) 39° 06' 6.7" 75° 12' 2.56"		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY Buchart-Horn, Inc.		12. MANUFACTURER'S DESIGNATION OF DRILL NA	
4. HOLE NO. (As shown on drawing title and file number)	DRV-21	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED	
5. NAME OF DRILLER Ocean Survey, Inc.		14. TOTAL NUMBER CORE BOXES NA	
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER NA	
7. THICKNESS OF OVERBURDEN NA		16. DATE HOLE : STARTED 07/18/91 : COMPLETED 07/18/91	
8. DEPTH DRILLED INTO ROCK NA		17. ELEVATION TOP OF HOLE -45.7 ft. NGVD	
9. TOTAL DEPTH OF HOLE 10 ft.		18. TOTAL CORE RECOVERY FOR BORING 14 ft.	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–3.6		Light red brown medium to fine sand with scattered gravel SP			Sample 0 - 5 ft.
	3.6–4.3		Light red brown sandy gravel GP			
	4.3–5.7		Light red brown medium to fine sand SP			Sample 4.3 - 5.7 ft.
	5.7–6.6		Dark grey silty sand SM			Sample 5.7 - 10 ft.
	6.6–7.1		Dark grey silty sand SM-SC			
	7.1–13.75		Dark grey clayey sand SM-SC			Sample 10 - 14 ft.
	13.75–14		Grey sandy silt			Bottom of recovery

PROJECT Delaware River Comprehensive Study — HOLE NO. DRV-21



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-21	0.0-5.0	Poorly-Graded Sand				
		SP				

Project Delaware River Vibracores

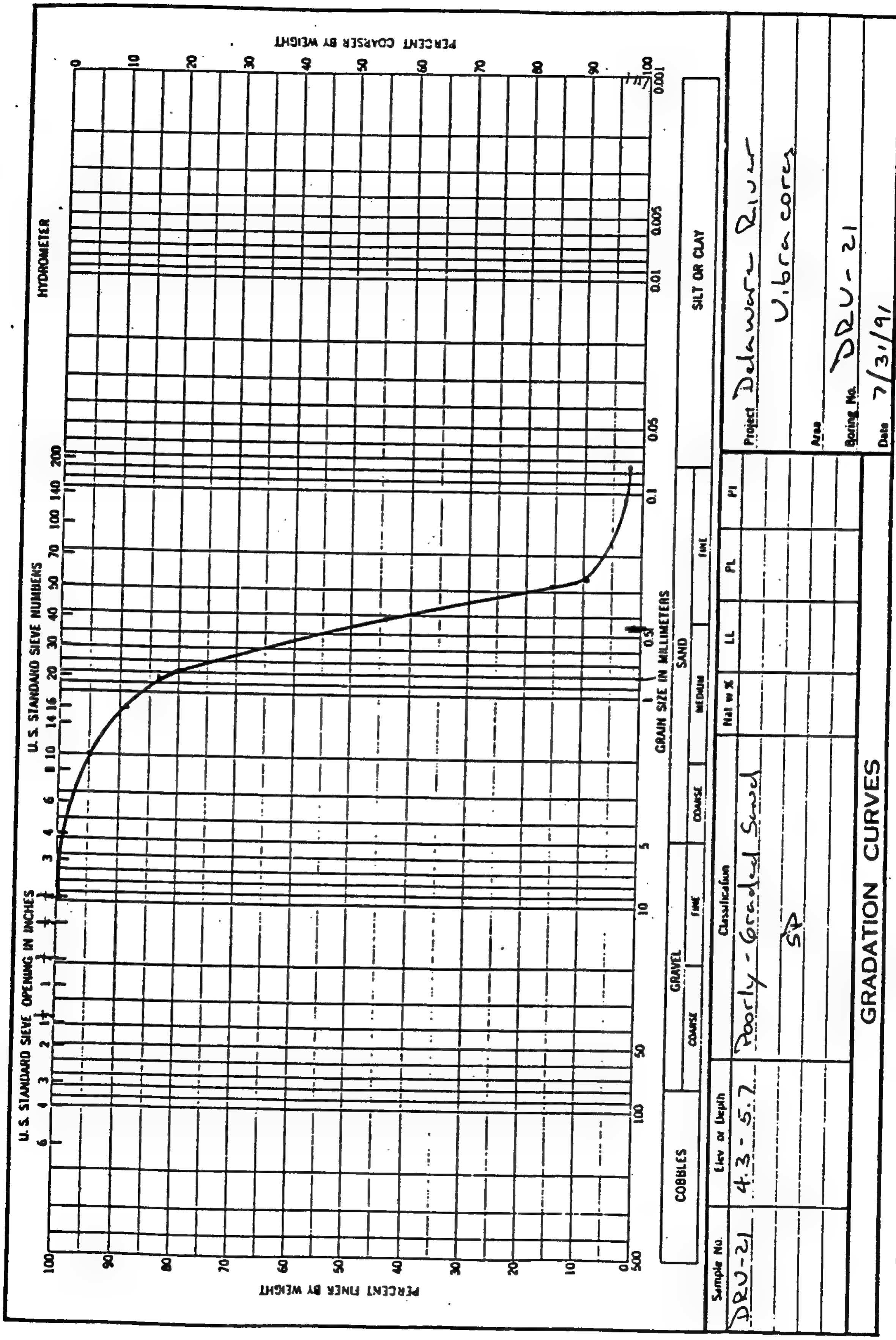
Area

Boring No. DRU-21

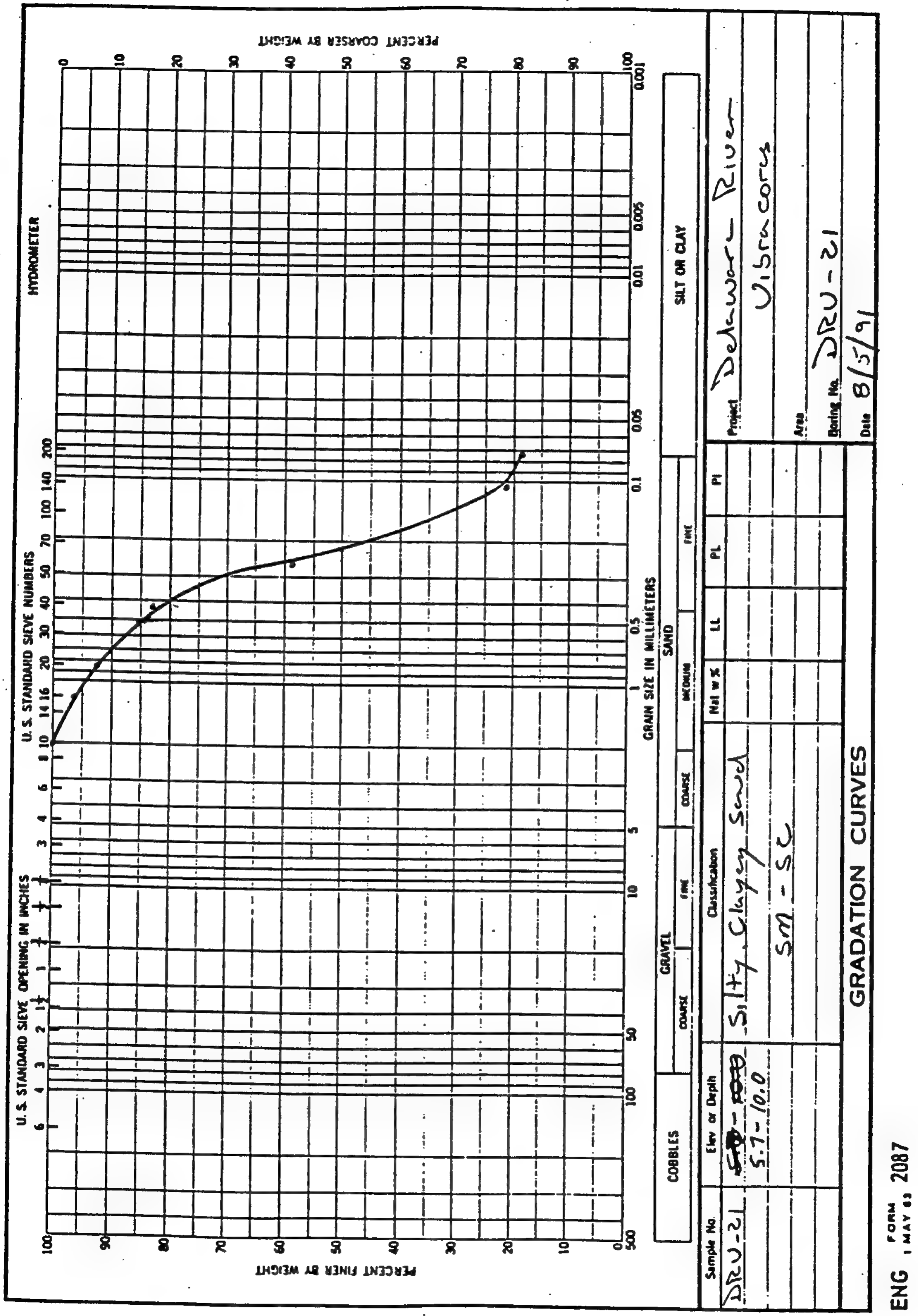
Date 8/6/91

GRADATION CURVES

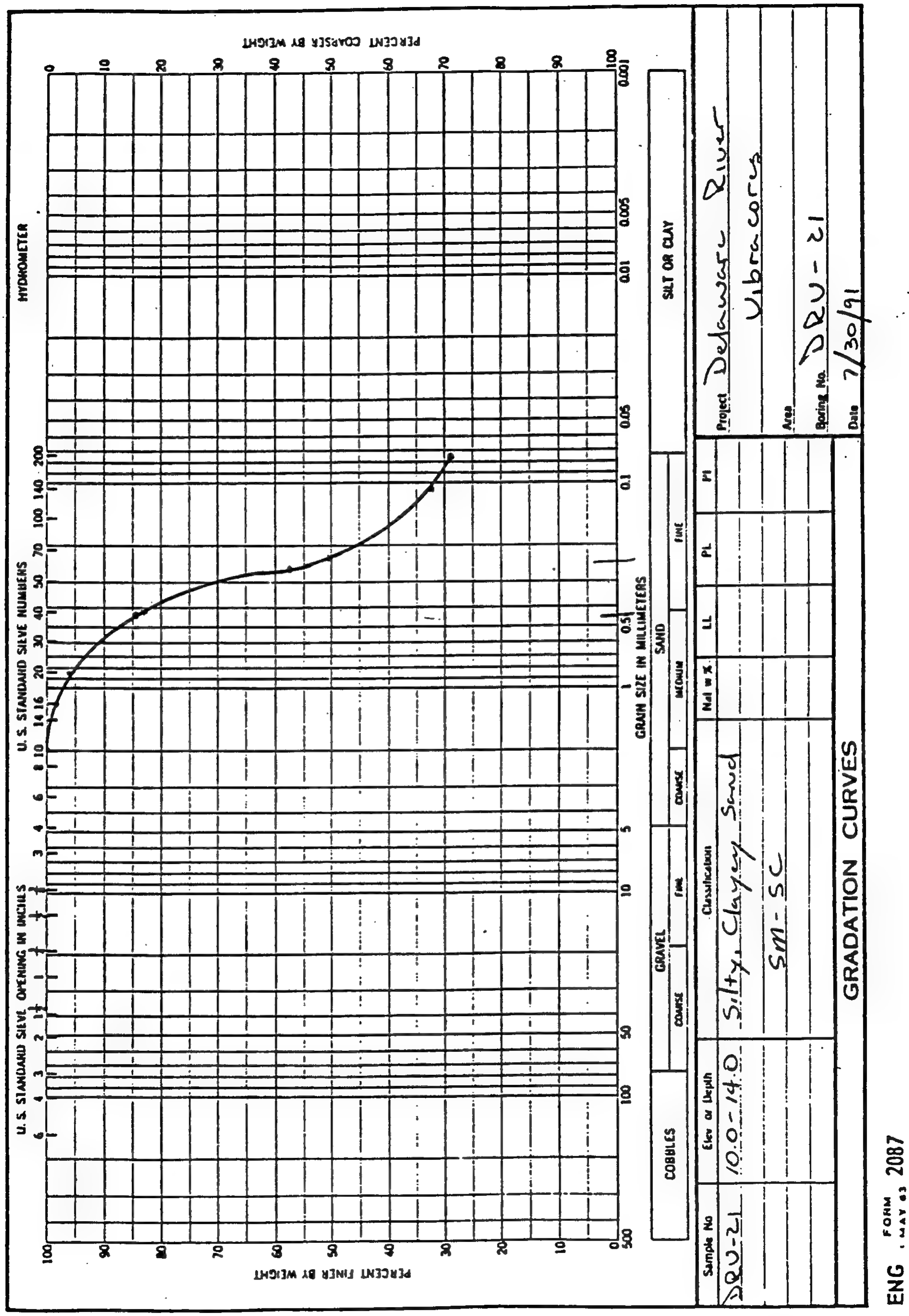
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRV-21
Elev or Depth 4.3-5.7
Classification Poorly-Graded Sand SP
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-21
Date 7/31/91
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRU-21
Elev or Depth 5.7-10.0
Classification Silty Clayey Sand SM-SC
Nat w% LL PL PI
Project Delaware River Vibracores
Area
Boring No. DRU-21
Date 8/5/91
ENG FORM 1 MAY 63 2087

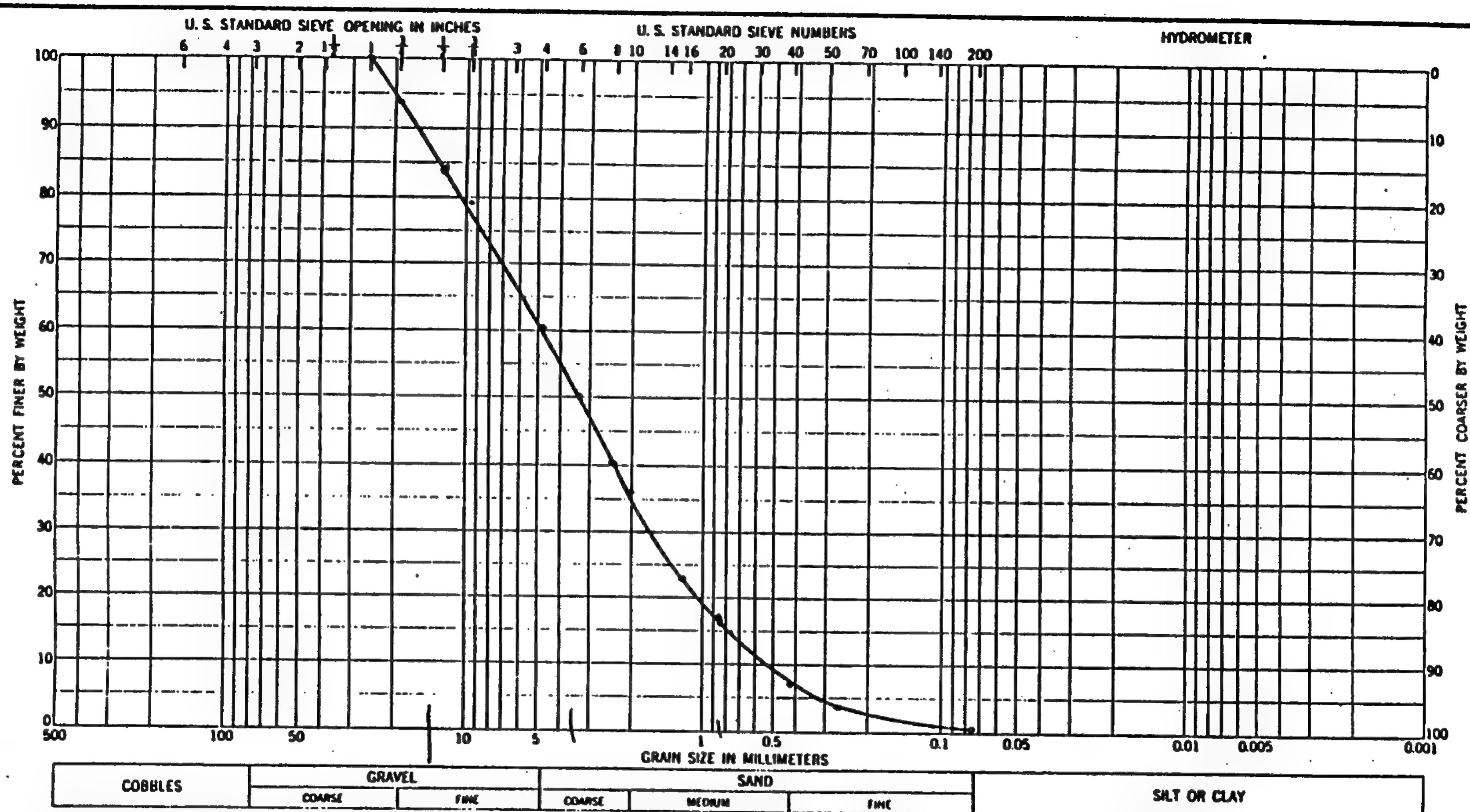

GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-21
Elev or Depth
10.0-14.0
Classification
Silty, Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-21
Date 7/30/91
ENG FORM 2087 MAY 63

Hole No. DRV-22

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT: Delaware River Comprehensive Study		10. SIZE AND TYPE OF BIT: Vibracore	
2. LOCATION (Coordinates or Station): 39° 05' 01.5" 75° 11' 03.94"		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY: Buchart-Horn, Inc.		12. MANUFACTURER'S DESIGNATION OF DRILL: NA	
4. HOLE NO. (As shown on drawing title and file number): DRV-22		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED : UNDISTURBED	
5. NAME OF DRILLER: Ocean Survey, Inc.		14. TOTAL NUMBER CORE BOXES: NA	
6. DIRECTION OF HOLE: VERTICAL INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NA	
7. THICKNESS OF OVERBURDEN: NA		16. DATE HOLE: STARTED 07/18/91 : COMPLETED 07/18/91	
8. DEPTH DRILLED INTO ROCK: NA		17. ELEVATION TOP OF HOLE: -48.9 ft. NGVD	
9. TOTAL DEPTH OF HOLE: 20 ft.		18. TOTAL CORE RECOVERY FOR BORING: 10.5 ft.	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Coarse to medium gravel some cobbles GP			Sample 0 - 1.0 ft.
	1		Black coarse to fine sandy gravel some cobble GP			
	1.6		Dark grey clay, piece of wood at 3 feet ML			Two jet retrys
	3					Sample 1.6 to 5.3 ft.
	5.3		Pockets of dark medium brown silt at 6.0 to 6.3, 6.9 to 7.0 9.3 to 9.7, 10.3 to 10.5 CH			
	7					Sample 7.0 - 9.2 ft.
	8					Two retries with jetting, unable to penetrate gravel
	10.6					Bottom of recovery

PROJECT: Delaware River Comprehensive Study — HOLE NO. DRV-22



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-22	0.0-1.0	Poorly-Graded Sand				
		SP				

Project Delaware River Vibracores

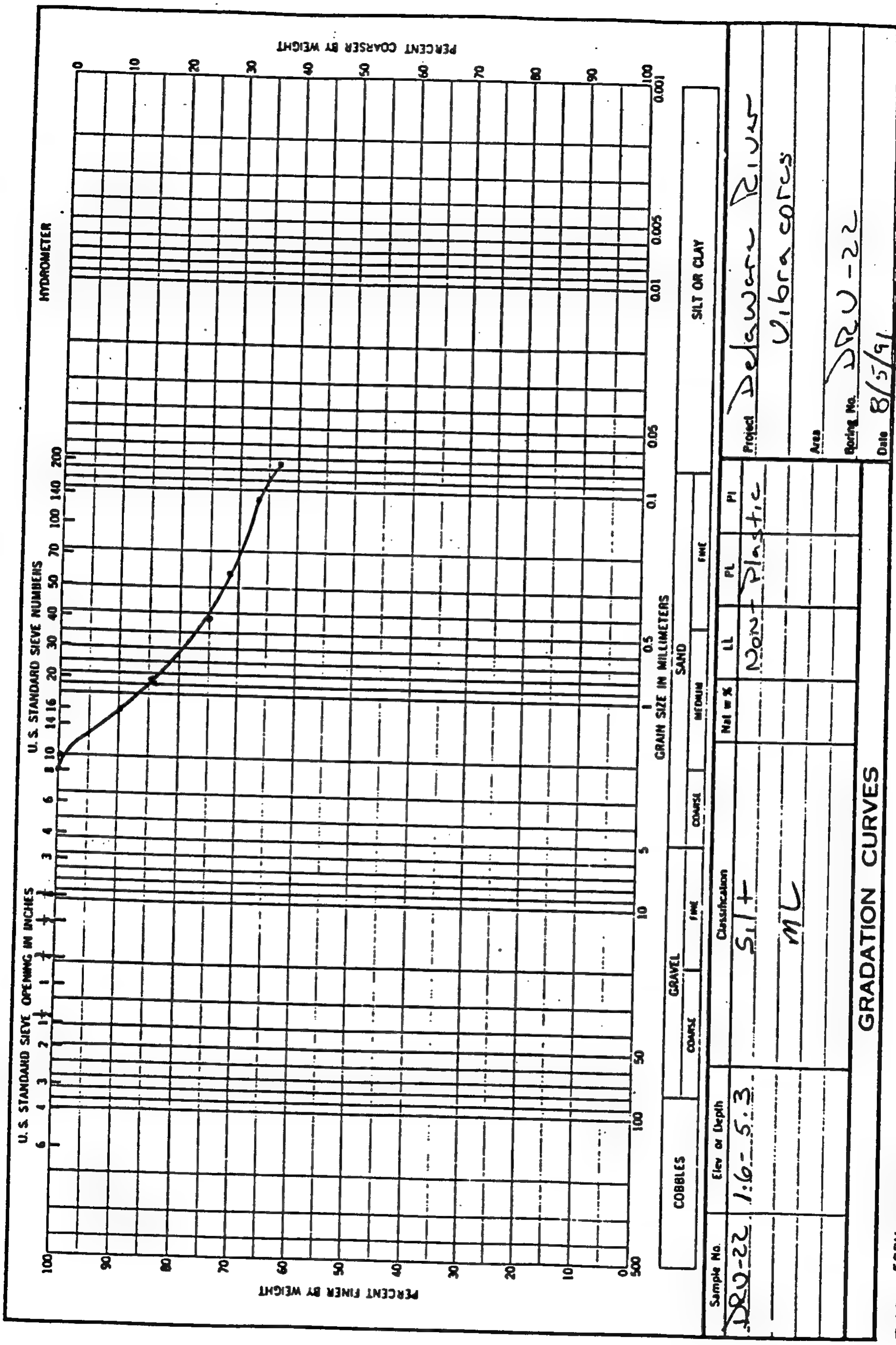
Area

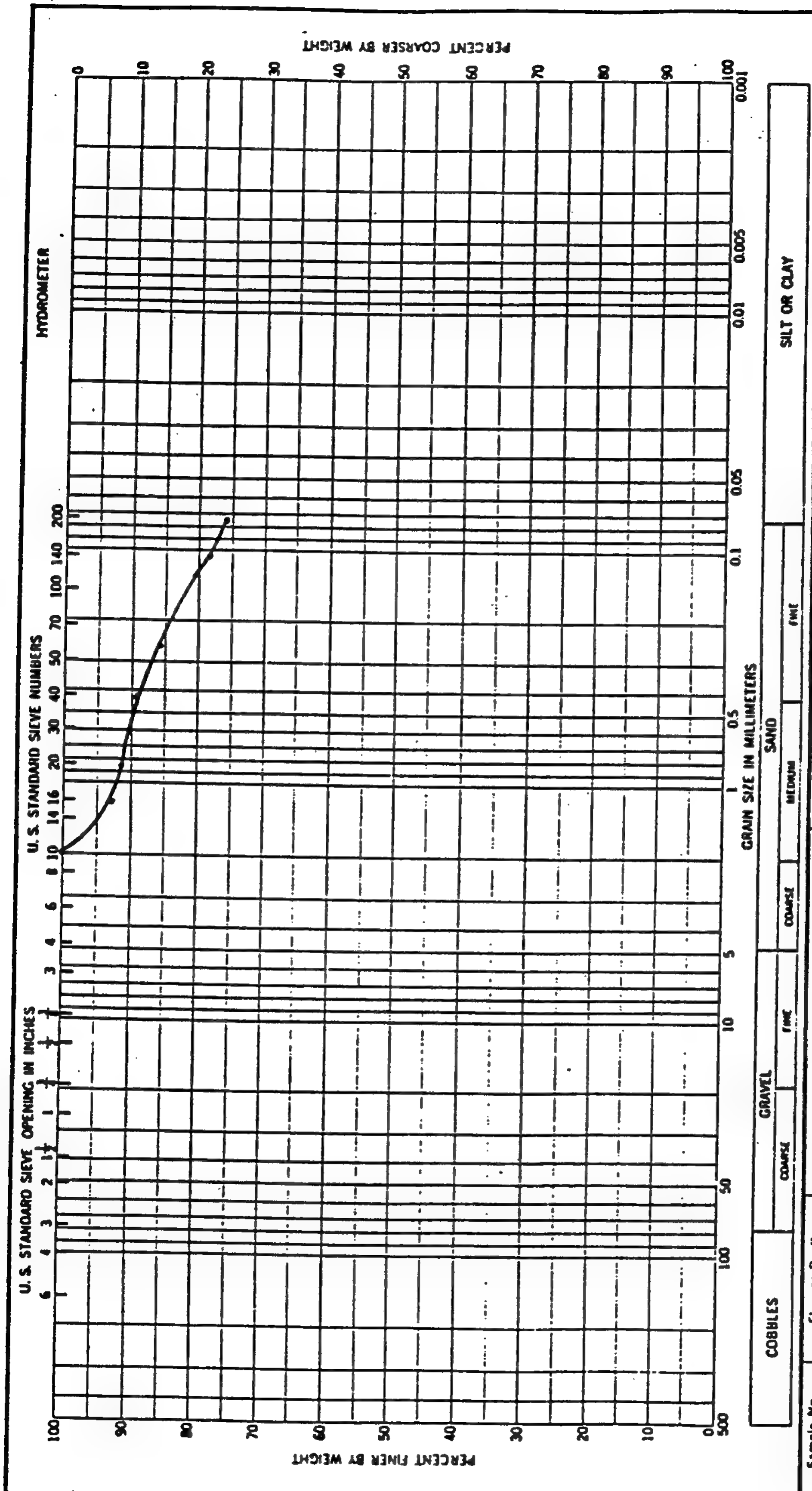
Boring No. DRU-22

Date 8/6/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRV-22
Elev or Depth
1.6-5.3
Classification
Silt
ML
Nat w %
LL
PL
PI
Non-Plastic
Project Delaware River
Vibracores
Area
Boring No. DRV-22
Date 8/5/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-22	7.0-9.2	Clay CH		50.8	23.7	27.1

Project Delaware River Vibracores

Area

Boring No. DRU-22

Date 8/5/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

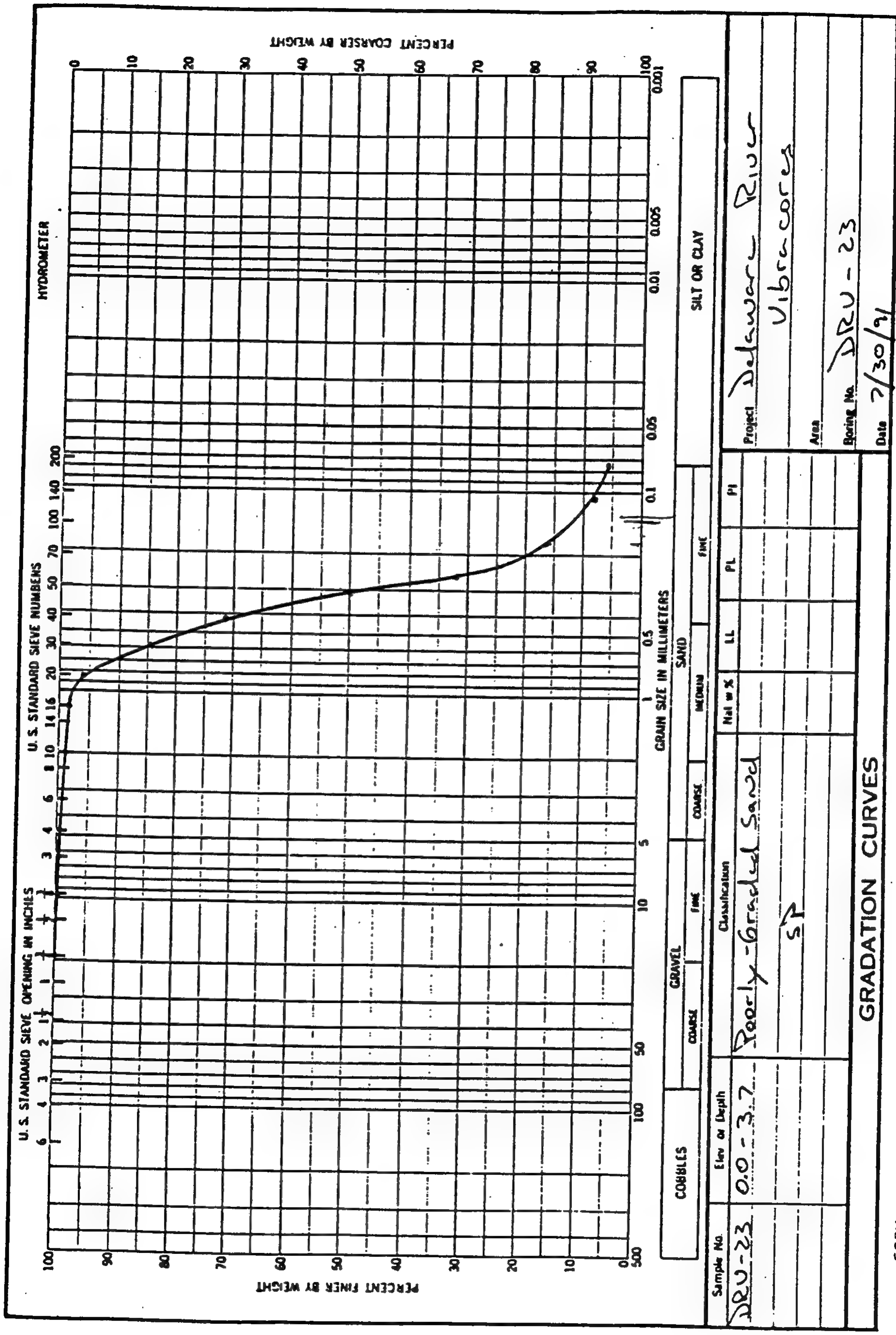
Hole No. DRV-23

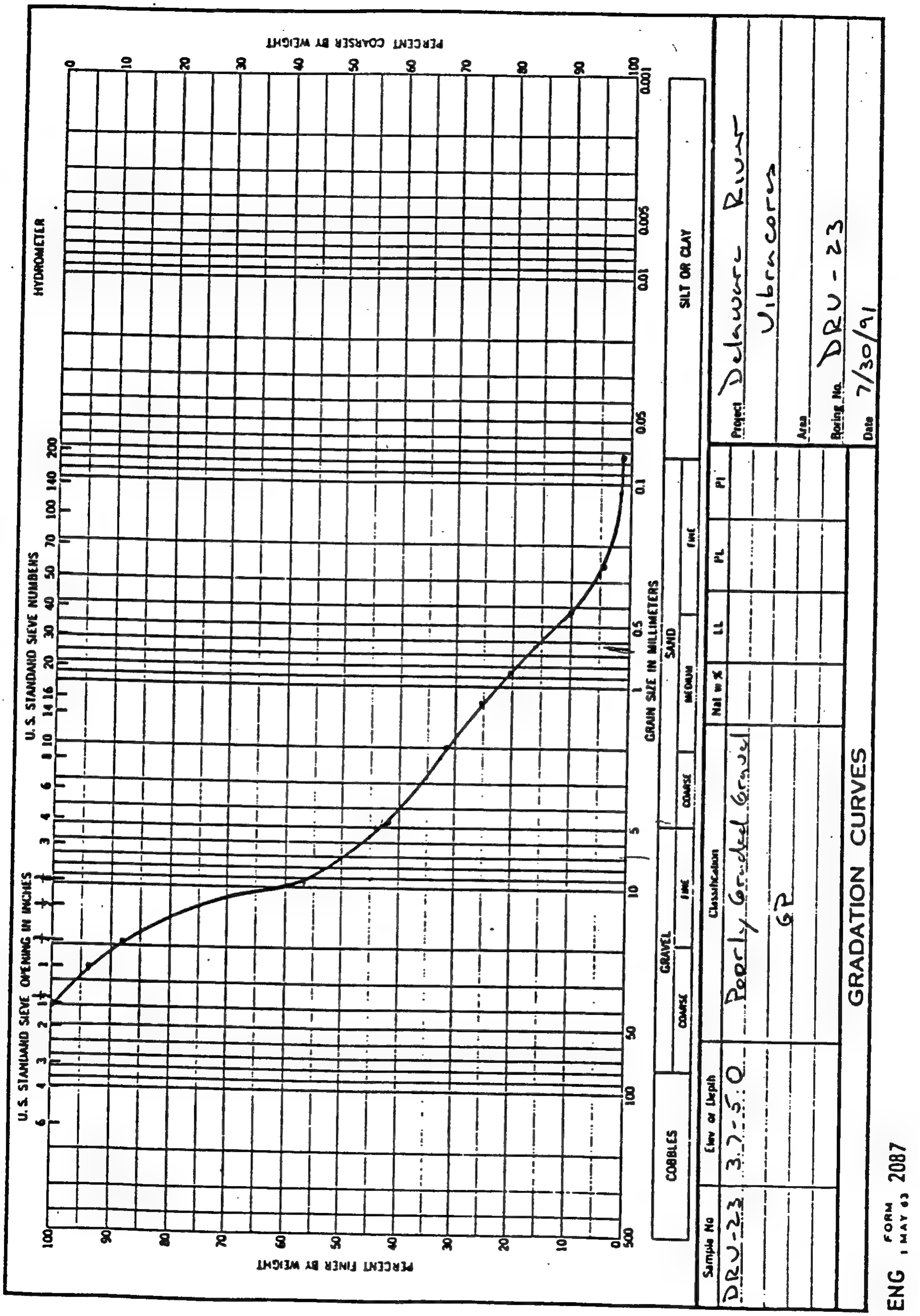
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station) 39° 03' 10.54" 75° 10' 7.61"	12. MANUFACTURER'S DESIGNATION OF DRILL NA
3. DRILLING AGENCY Buchart-Horn, Inc.	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
4. HOLE NO. (As shown on drawing title and file number) DRV-23	14. TOTAL NUMBER CORE BOXES NA
5. NAME OF DRILLER Ocean Survey, Inc.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE : STARTED 07/17/91 : COMPLETED 07/17/91
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	17. ELEVATION TOP OF HOLE -47.8 ft. NGVD
7. THICKNESS OF OVERBURDEN NA	18. TOTAL CORE RECOVERY FOR BORING 12.8 ft.
8. DEPTH DRILLED INTO ROCK NA	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE 15.5 ft.	

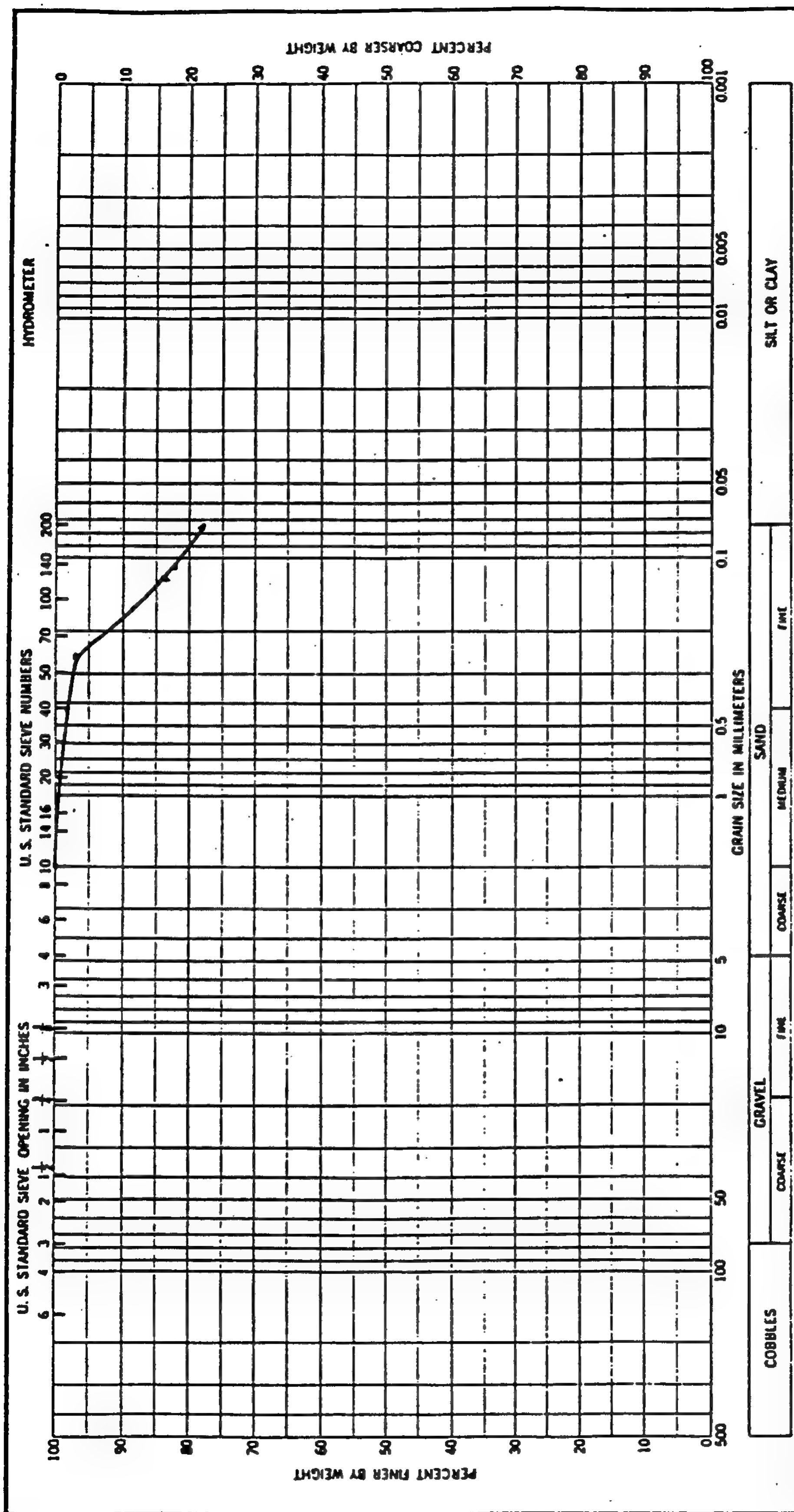
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Grey and grey brown mixed fine sand with shells SP			Sample 0 - 3.7 ft.
	2		Light grey fine sand			
	3.7		Sandy gravel-brown, coarse to fine gravel with coarse to fine sand GP			Sample 3.7 - 5.0 ft.
	5		Varying to gravelly coarse to fine sand			
	8.1		White fine to medium sand SP			Sample 8.3 - 9.2 ft.
	8.3		Red brown clay CL			
	9.2		Grey silty sand SM-SC			Sample 9.2 - 13 ft.
	11.5		Becoming finer with depth			
	12.8					Bottom of recovery

PROJECT Delaware River Comprehensive Study — HOLE NO. DRV-23


GRADATION CURVES
Project Delaware River Vibracores
Area
Boring No. DRV-23
Date 7/30/91
Sample No. DRV-23
Elev or Depth 0.0-3.7
Classification Poorly-Graded Sand SP
Nat w %
LL
PL
PI
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-23
Elev or Depth
3.7-5.0
Classification
Poorly Graded Gravel
GP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-23
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-23	8.3-9.2	Clay		32.3	20.65	11.65
		CL				

Project Delaware River Vibracores

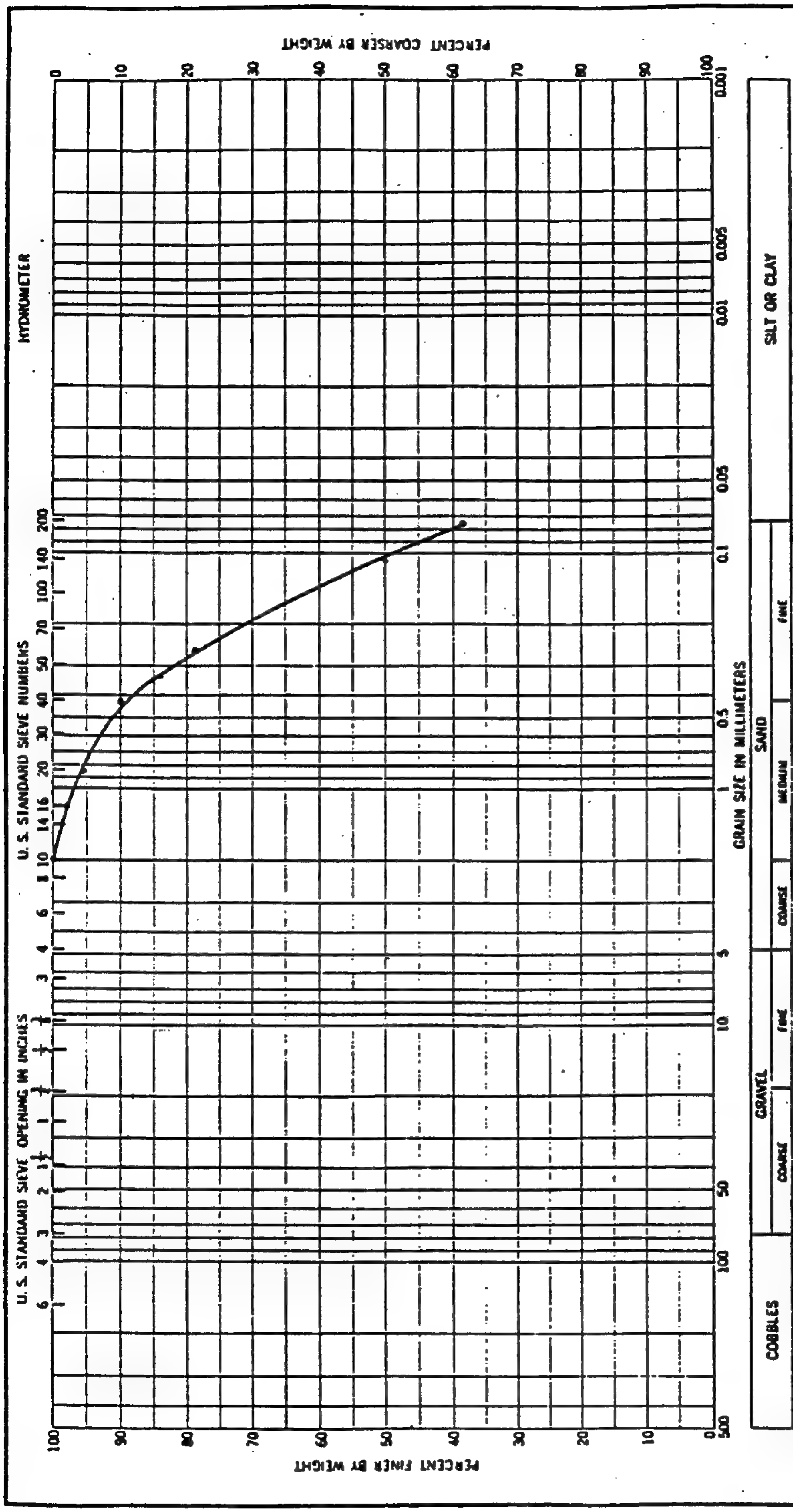
Area

Boring No. DRU-23

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRV-23	9.2-13.0	Silty Clayey Sand SM-SC				

Project: Delaware River Vibracores

Area:

Boring No.: DRV-23

Date: 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087

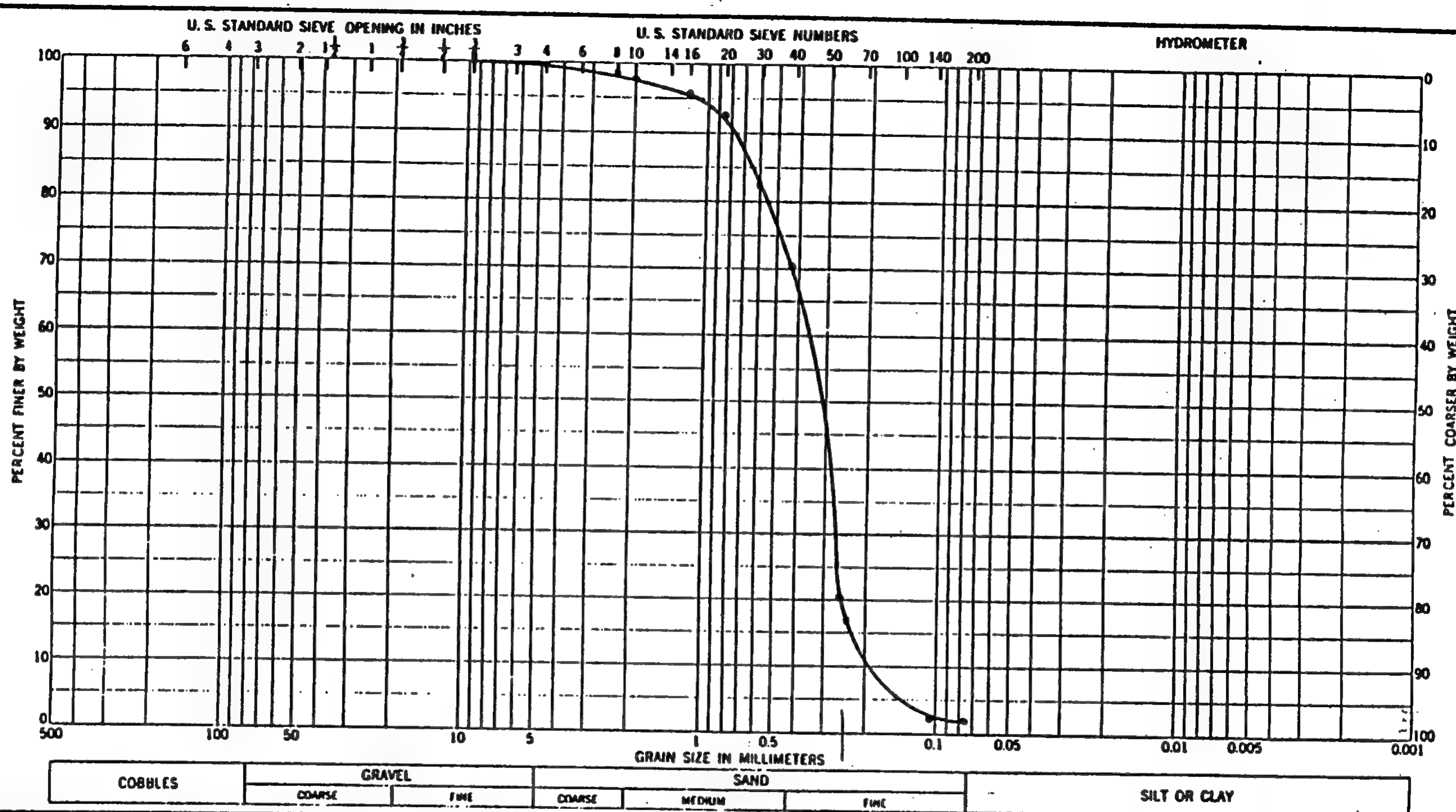
Hole No. DRV-24

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 01' 40" 75° 09' 18.02"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-24	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/17/91 : COMPLETED 07/17/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -47.1 ft. NGVD
9. TOTAL DEPTH OF HOLE 19 ft.	18. TOTAL CORE RECOVERY FOR BORING 15.4 ft.
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0–3		Medium to fine dark grey micaceous sand with some shells SP			Sample 0 - 3 ft.
	3–5		Light grey medium to fine sand micaceous....			
	5–10		...with locally coarse to fine quartz sand zones SP			Sample 5 - 10 ft.
	11.6–13.6		Grey medium to fine sand SP			Sample 11.6 - 13.6 ft.
	13.6–14.6		Grey brown (tan?) to light grey very coarse to fine gravelly sand, one cobble SP			Sample 13.6 - 15.6 ft.
	14.6–15.6		Light grey medium to fine sand with trace of gravel SP			
	15.6–16		Gravelly sand SP			Bottom of recovery

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-24



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-24	0.0-3.0	Poorly-Graded Sand				
		SP				

Project Delaware River
Vibracores

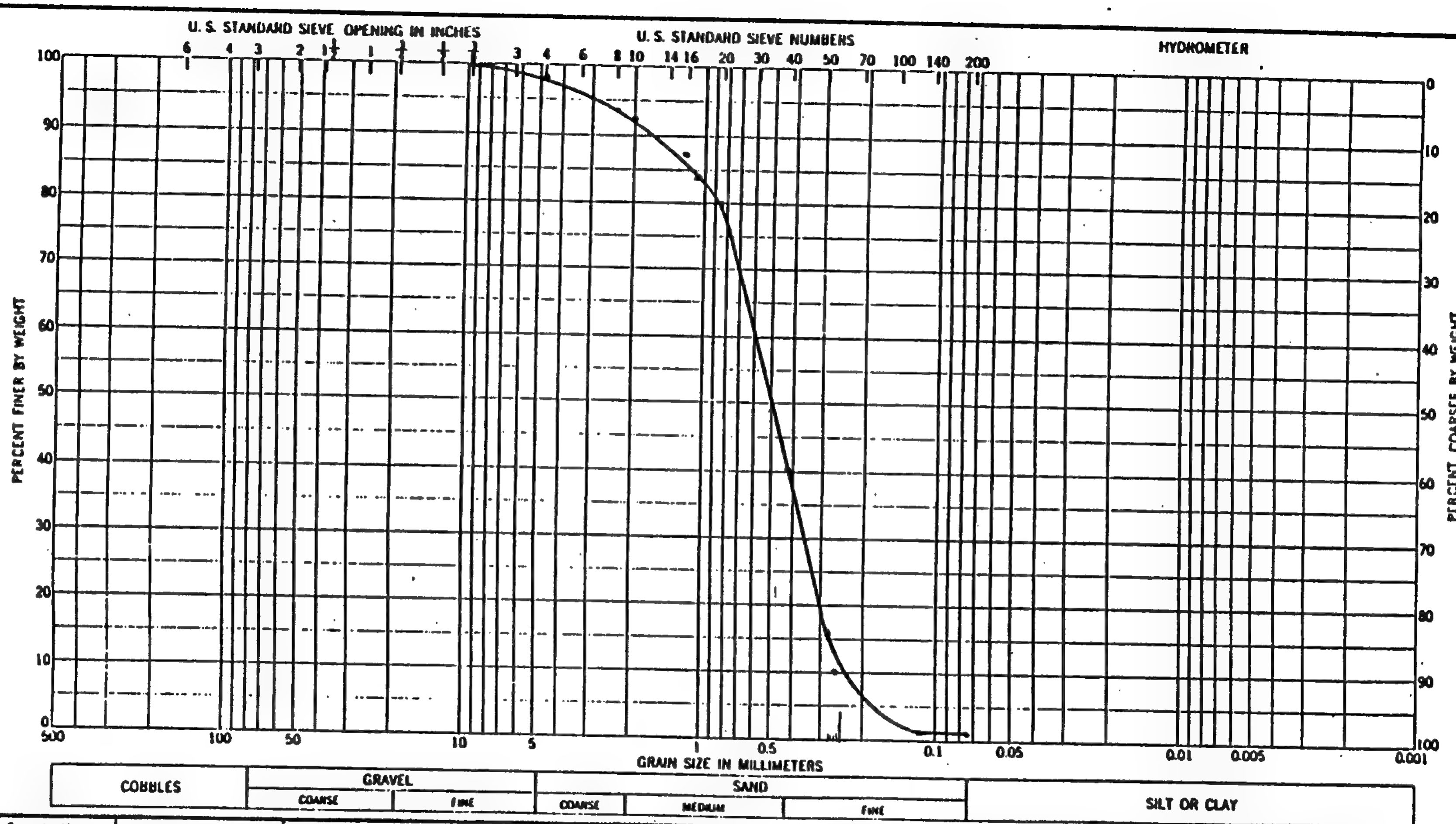
Area

Boring No. DRU-24

Date 8/6/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-24	5.0-10.0	Poorly-Graded Sand				
		SP				

Project Delaware River Vibracores

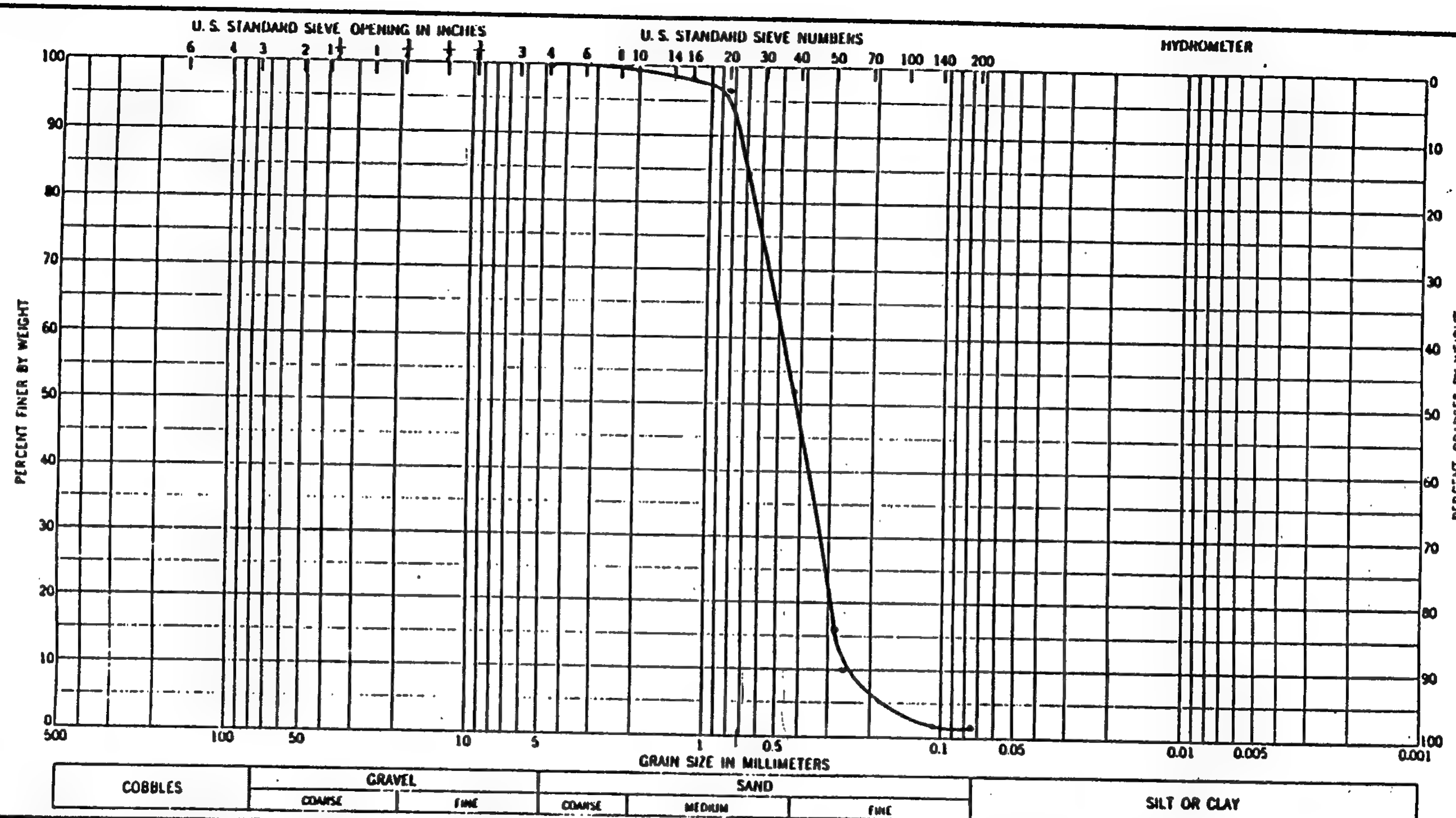
Area

Boring No. DRU-24

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-24	11.6-13.6	Poorly-Graded Sand SP				

Project Delaware River Vibracores

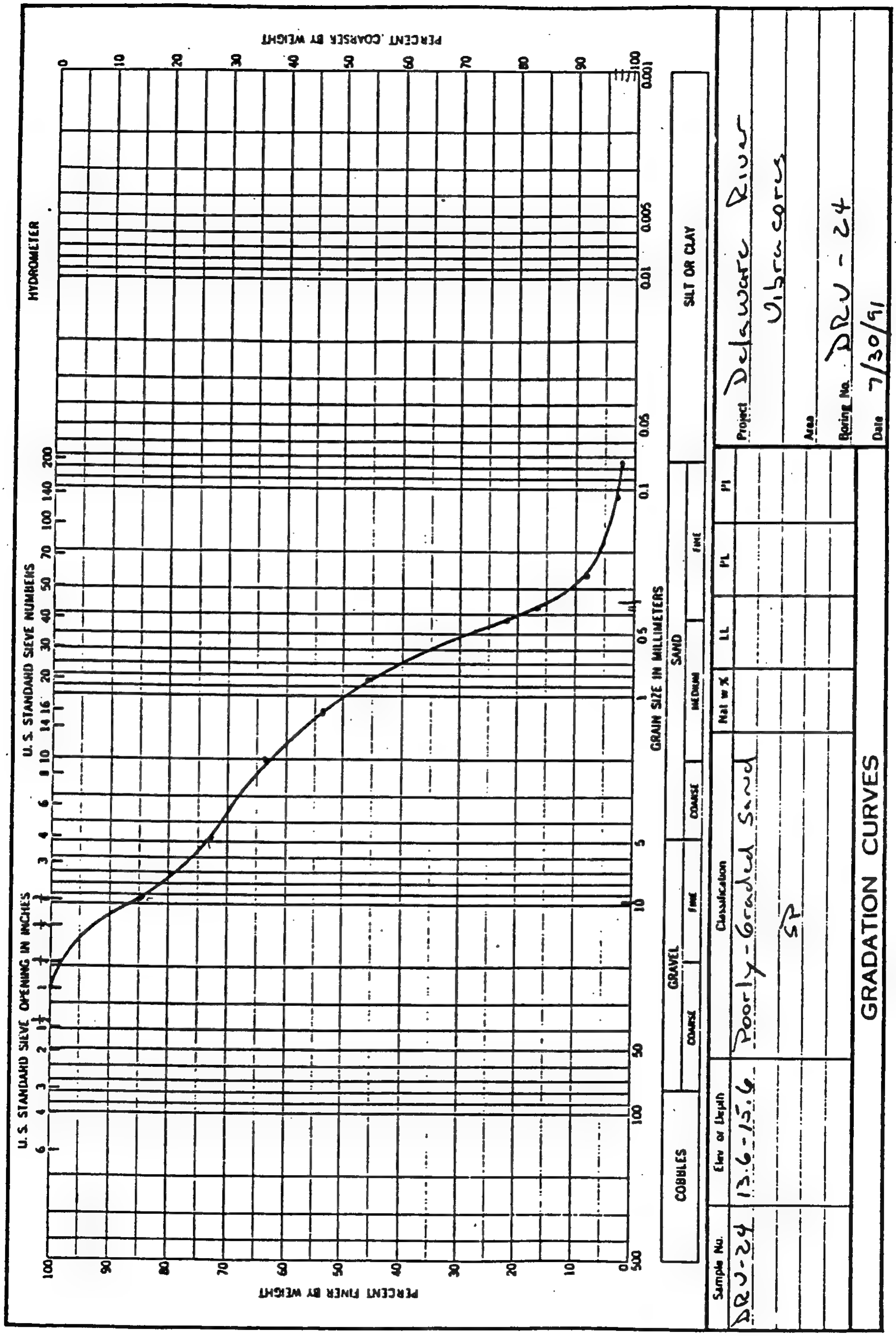
Area

Boring No. DRU-24

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRV-24
Elev or Depth 13.6-15.6
Classification Poorly-Graded Sand SP
Nat w % LL PL PI
Project Delaware River Vibracores
Area
Boring No. DRV-24
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

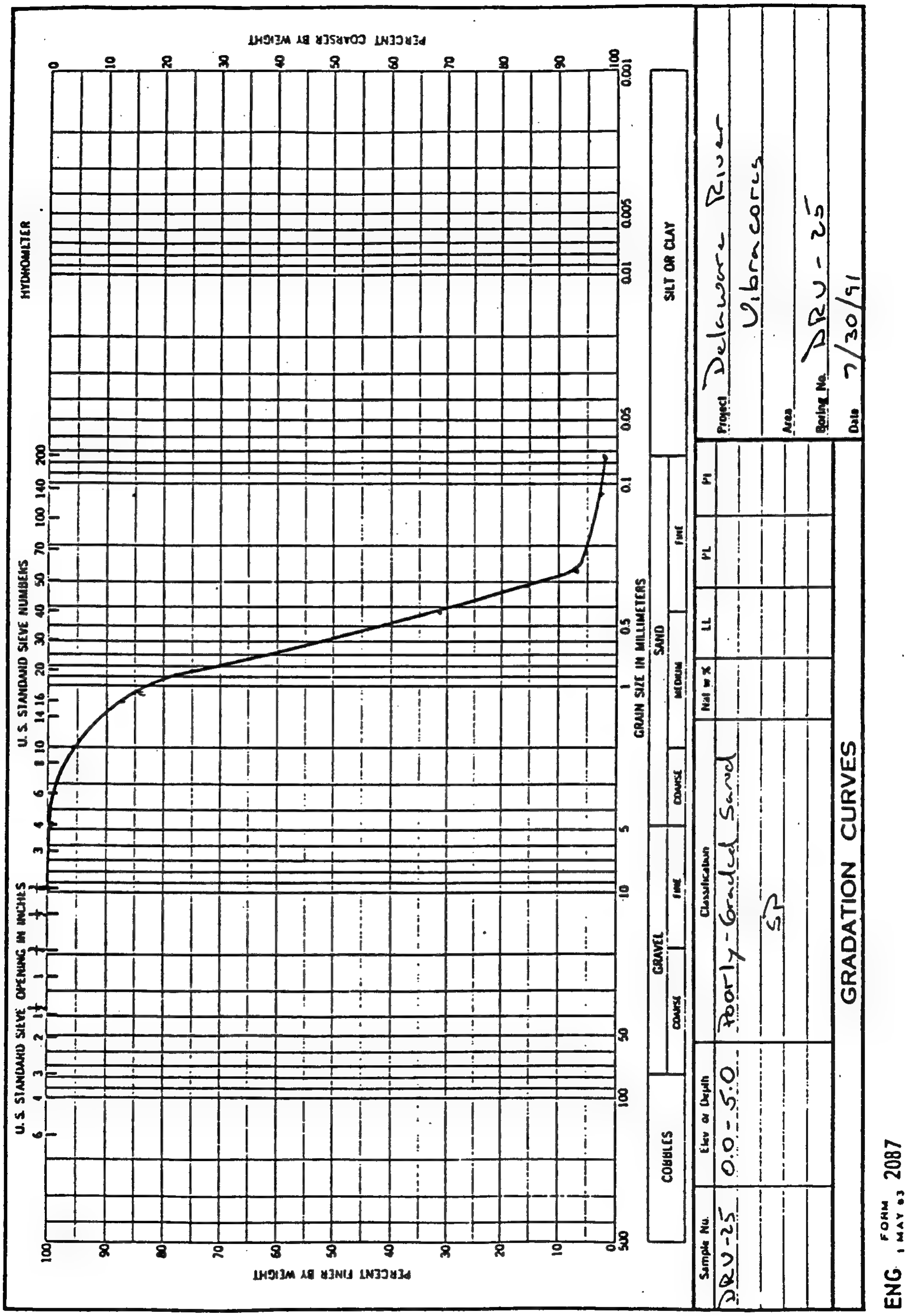
Hole No. DRV-25

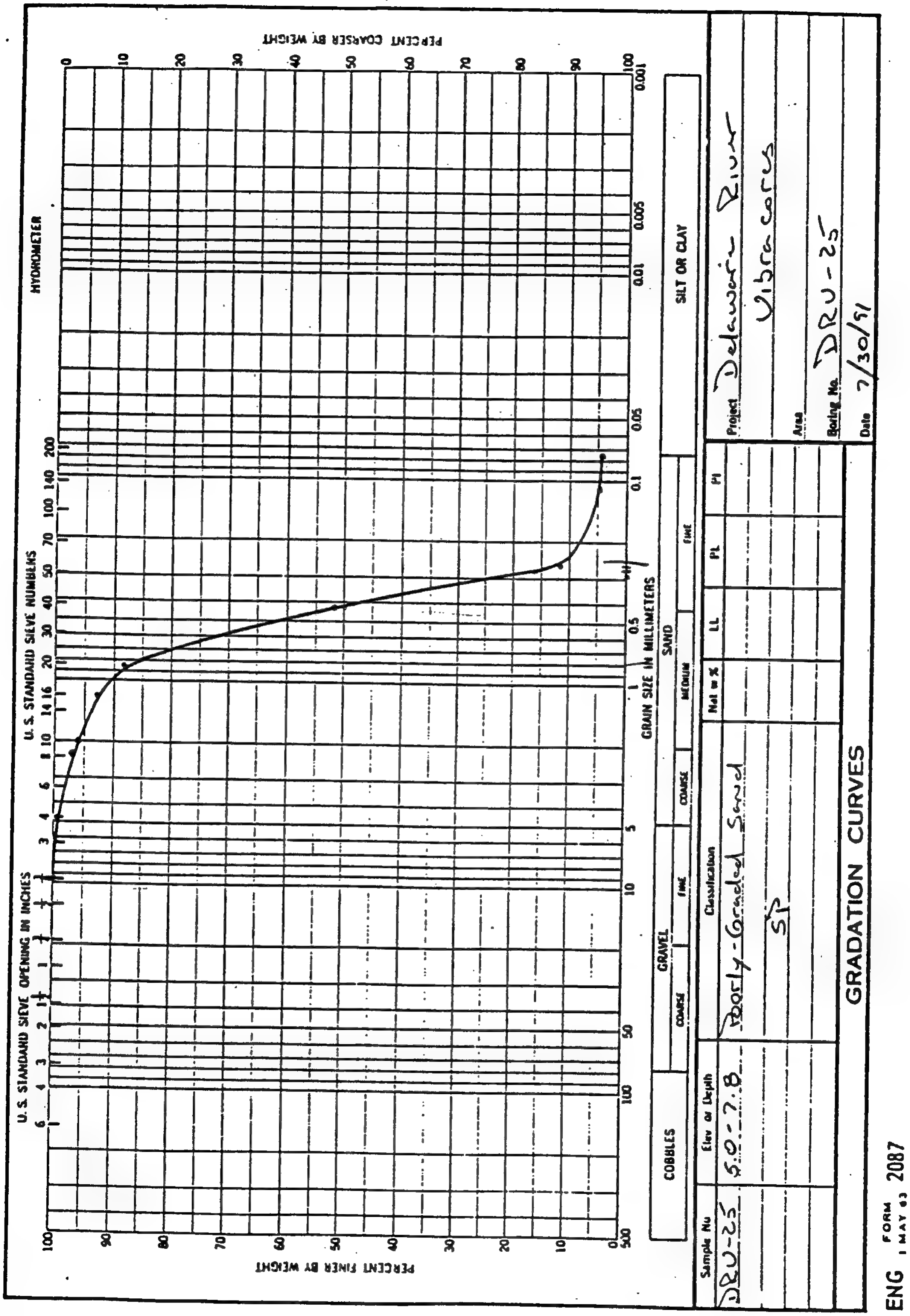
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

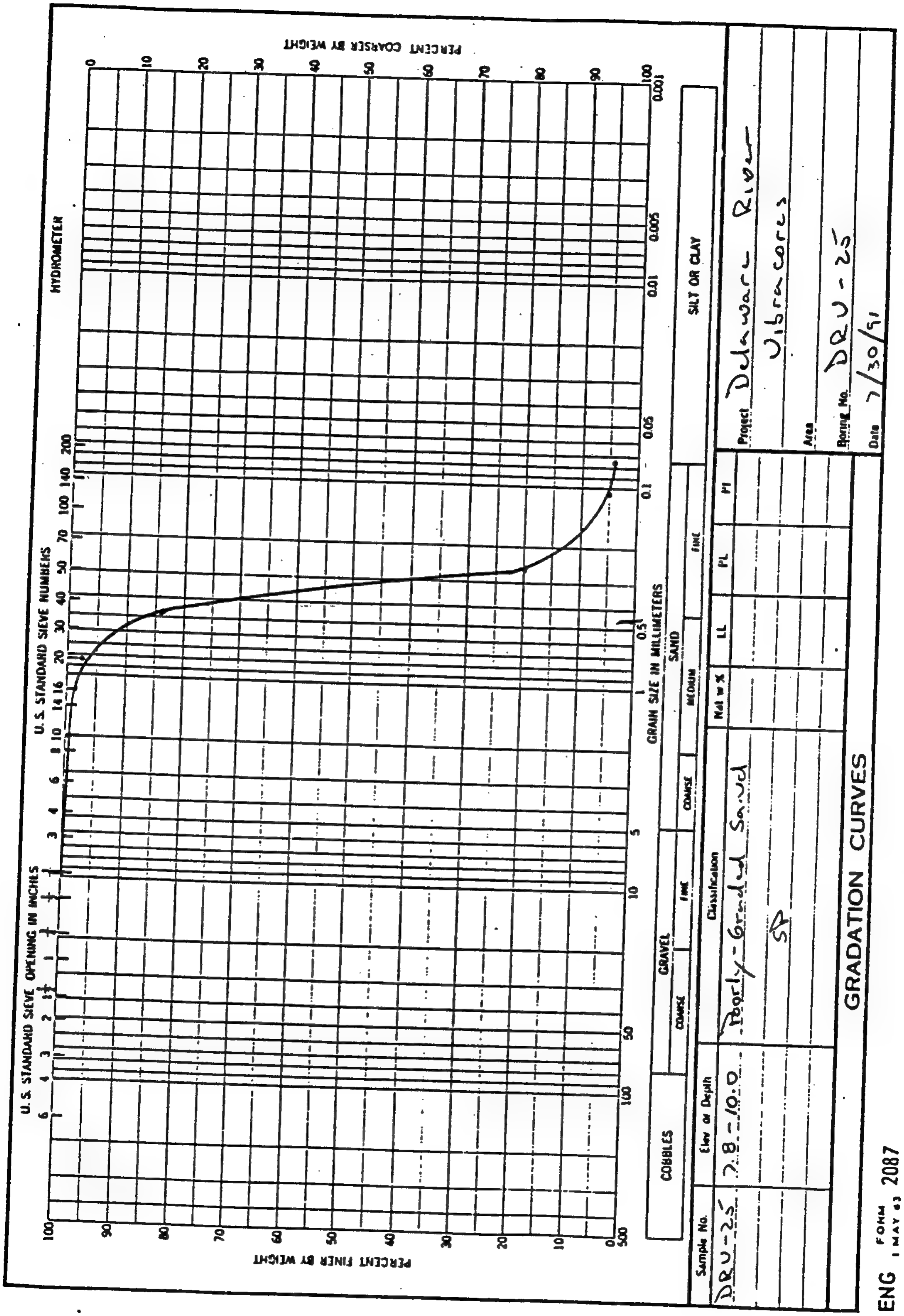
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
2. LOCATION (Coordinates or Station) 39° 00' 9.85" 75° 08' 26.36"	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Buchart-Horn, Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL NA
4. HOLE NO. (As shown on drawing title and file number) DRV-25	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
5. NAME OF DRILLER Ocean Survey, Inc.	14. TOTAL NUMBER CORE BOXES NA
6. DIRECTION OF HOLE VERTICAL INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
7. THICKNESS OF OVERBURDEN NA	16. DATE HOLE : STARTED 07/17/91 : COMPLETED 07/17/91
8. DEPTH DRILLED INTO ROCK NA	17. ELEVATION TOP OF HOLE -44.4 ft. NGVD
9. TOTAL DEPTH OF HOLE 20 ft.	18. TOTAL CORE RECOVERY FOR BORING 19.8 ft.
	19. SIGNATURE OF INSPECTOR

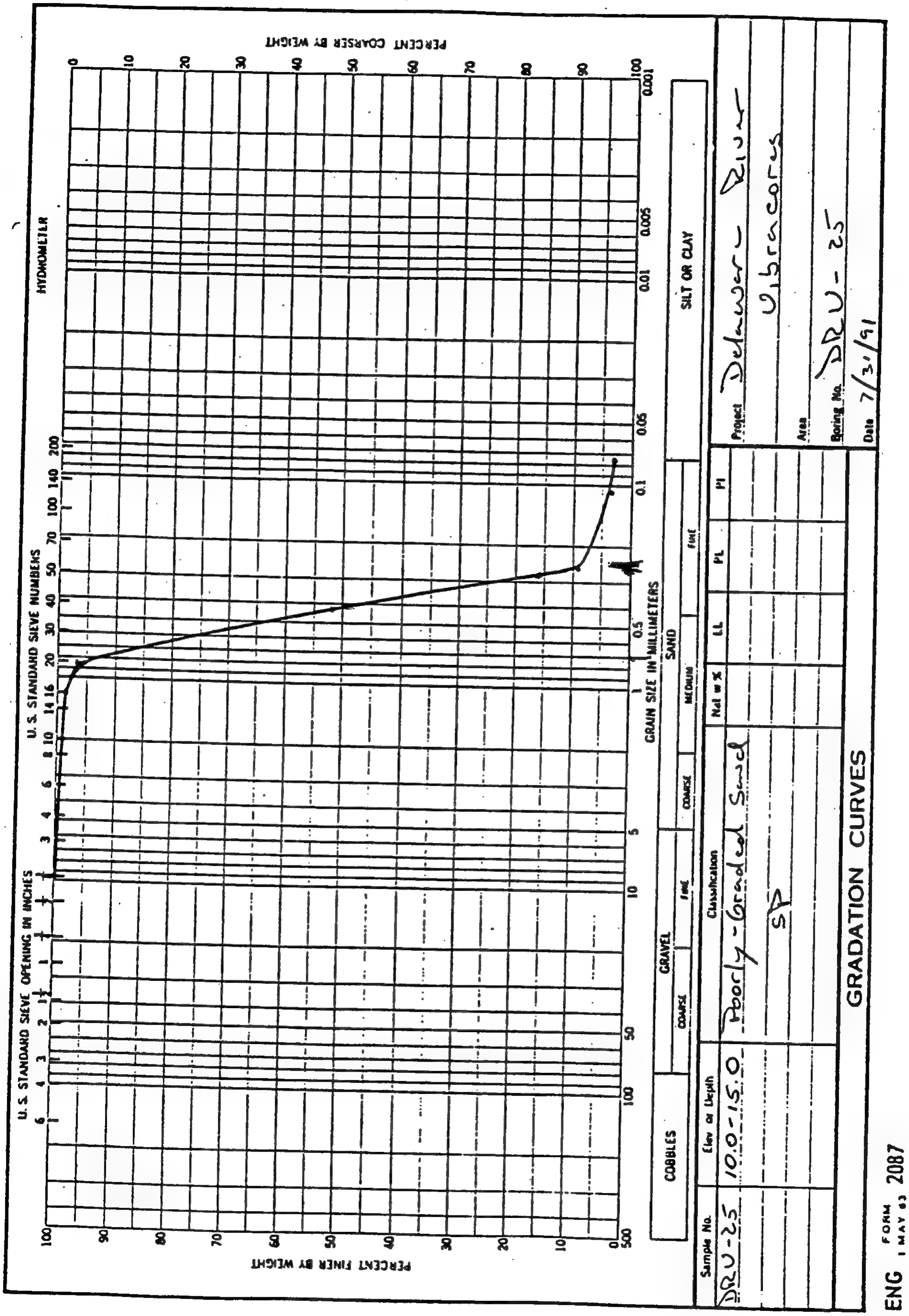
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0–4.2		Brown sand with some silt Coarse to fine sand, micaceous SP			Sample 0 - 5 ft.
	4.2–4.4		Grey silt clay SM-SC			
	4.4–5.8		Brown sand SP coarse to fine micaceous			Sample 5 - 7.8 ft.
	5.8–7.4		Medium to fine brown sand SP			
	7.4–7.8		Coarse to fine grey sand, quartz			
	7.8–10		Gray fine sand, micaceous SP			Sample 7.8 - 10 ft.
	10–15.3		Some 0.5 ft. clay lenses Medium to fine grey sand, micaceous, grey quartz, thin layers of fine sand SP			Sample 10 - 15 ft.
	15.3–15.8		Coarse sand with gravel SP			
	15.8–16.7		Medium to fine grey sand, quartz SP			
	16.7–17.5		Grey coarse sand with gravel SP			Sample 16.5 - 17.5 ft.
	17.5–20		Silt, micaceous, dark grey ML			Sample 17.5 - 20 ft.

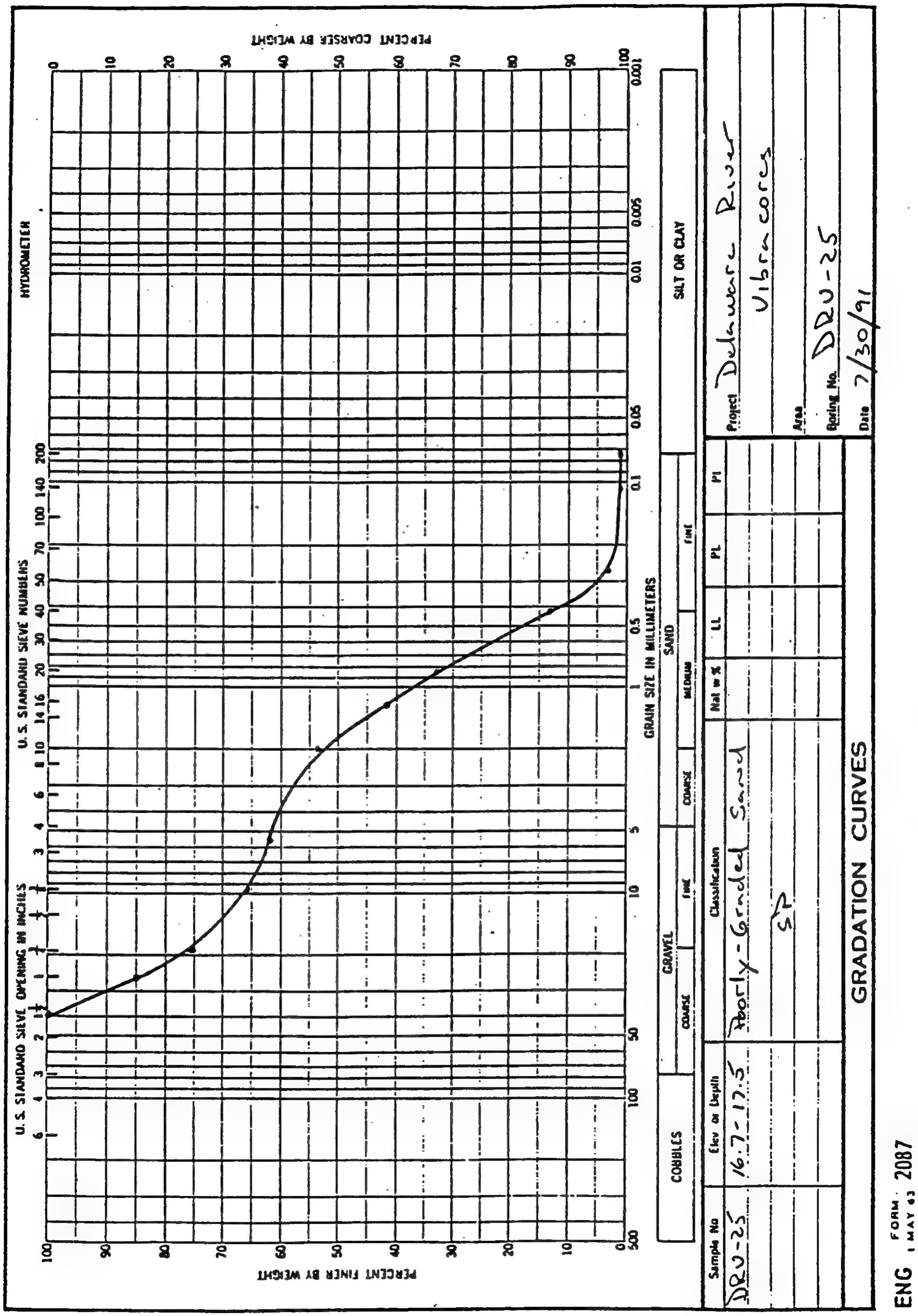
PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-25


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRU-25
Elev or Depth
0.0-5.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-25
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

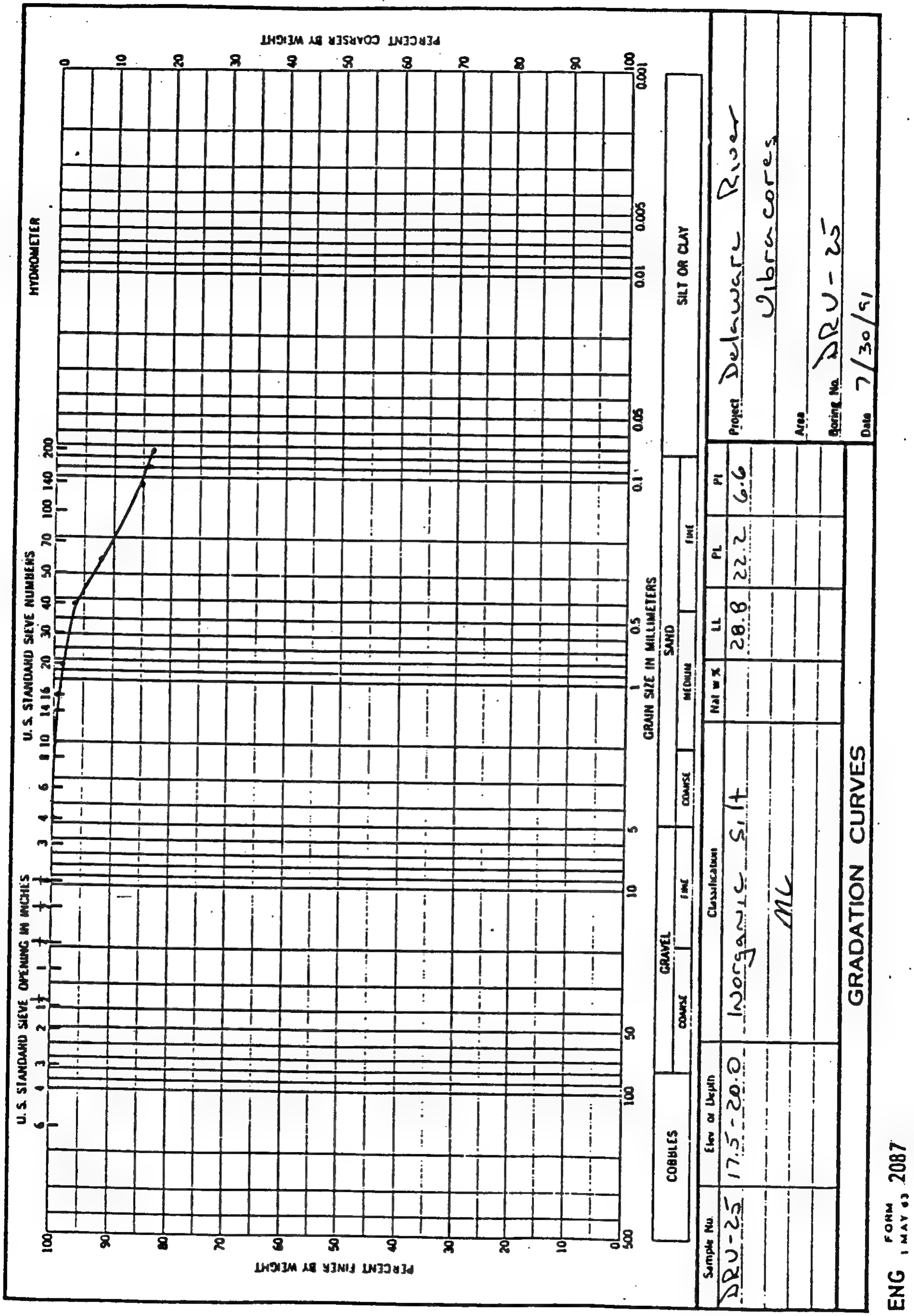

PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-25
Elev or Depth
5.0-7.8
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRU-25
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRV-25
Elev or Depth
7.8-10.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-25
Date 7/30/91
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No. DRU-25
Elev or Depth 10.0-15.0
Classification Poorly-Graded Sand SP
Project Delaware River Vibracores
Boring No. DRU-25
Date 7/31/91
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No DRV-25
Elev or Depth 16.7-17.5
Classification Poorly-Graded Sand SP
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-25
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRV-25
Elev or Depth 17.5-20.0
Classification Inorganic Silt
ML
Nat w %
LL 28.8
PL 22.2
PI 6.6
Project Delaware River
Vibracores
Area
Boring No. DRV-25
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

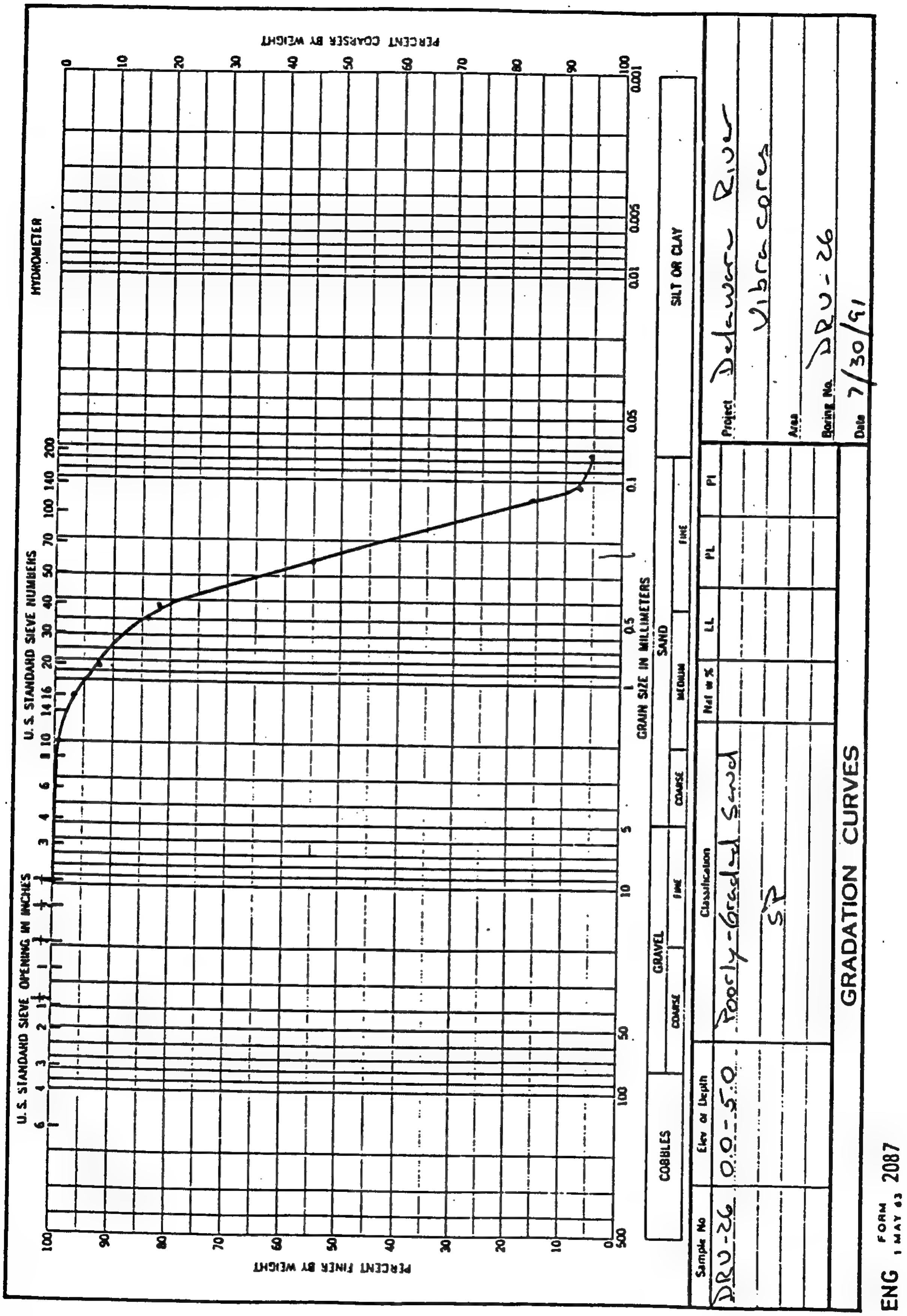
Hole No. DRV-26

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

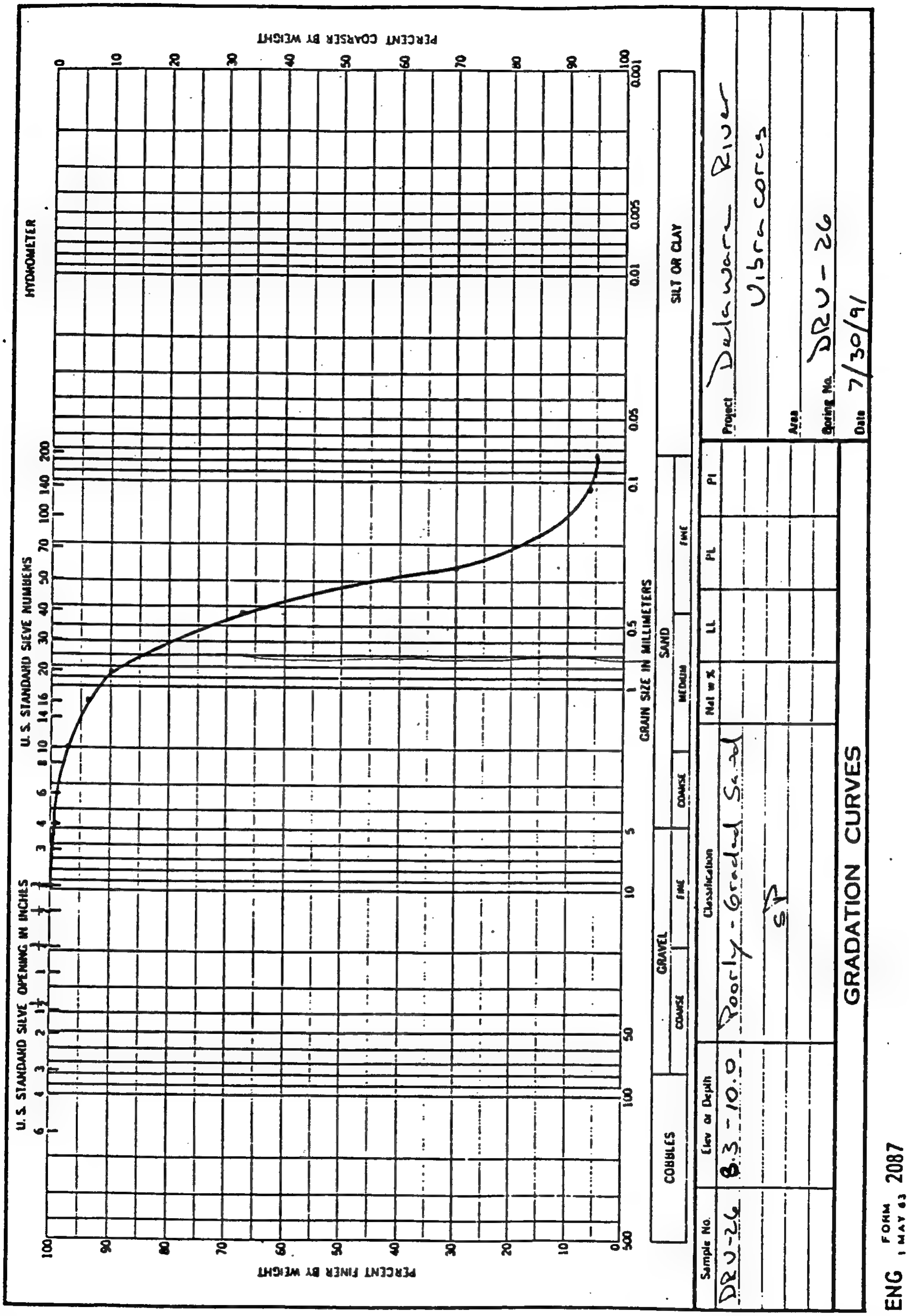
1. PROJECT Delaware River Comprehensive Study	10. SIZE AND TYPE OF BIT Vibracore
	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station) 38° 57' 7.9" 75° 06' 46.38"	12. MANUFACTURER'S DESIGNATION OF DRILL NA
3. DRILLING AGENCY Buchart-Horn, Inc.	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED
4. HOLE NO. (As shown on drawing title and file number) DRV-26	14. TOTAL NUMBER CORE BOXES NA
	15. ELEVATION GROUND WATER NA
5. NAME OF DRILLER Ocean Survey, Inc.	16. DATE HOLE : STARTED 07/16/91 : COMPLETED 07/16/91
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.	17. ELEVATION TOP OF HOLE -46.3 ft. NGVD
7. THICKNESS OF OVERBURDEN NA	18. TOTAL CORE RECOVERY FOR BORING 16 ft.
8. DEPTH DRILLED INTO ROCK NA	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE 20 ft.	

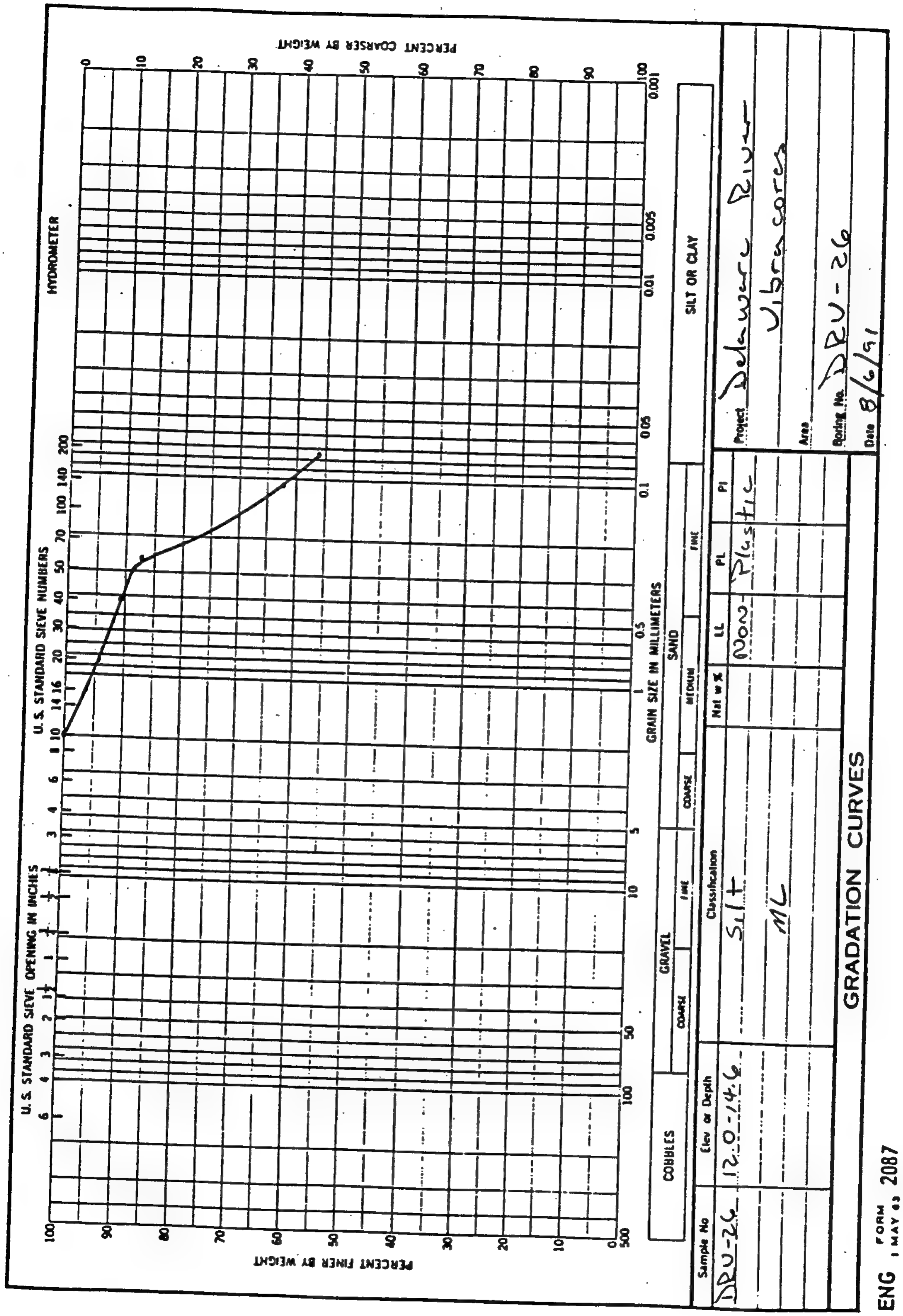
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–1		Grey sand with black stains SP			
	1–5		Grey sand with scattered shells siltier with depth SP			Sample 0 - 5.0 ft.
	5–7.1		Grey sand SP			
	7.1–8.3		Red brown sand, interbedded with grey SP			
	8.3–10		Red brown sand SP			Sample 8.3 - 10 ft.
	10–12		SP			
	12–13.3		Grey silt ML			
	13.3–14.6		Red silt ML			Sample 12 - 14.6 ft.
	14.6–16		Red brown silty sand SM-SC			Sample 14.6 - 16 ft.
	16					Bottom of recovery

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-26

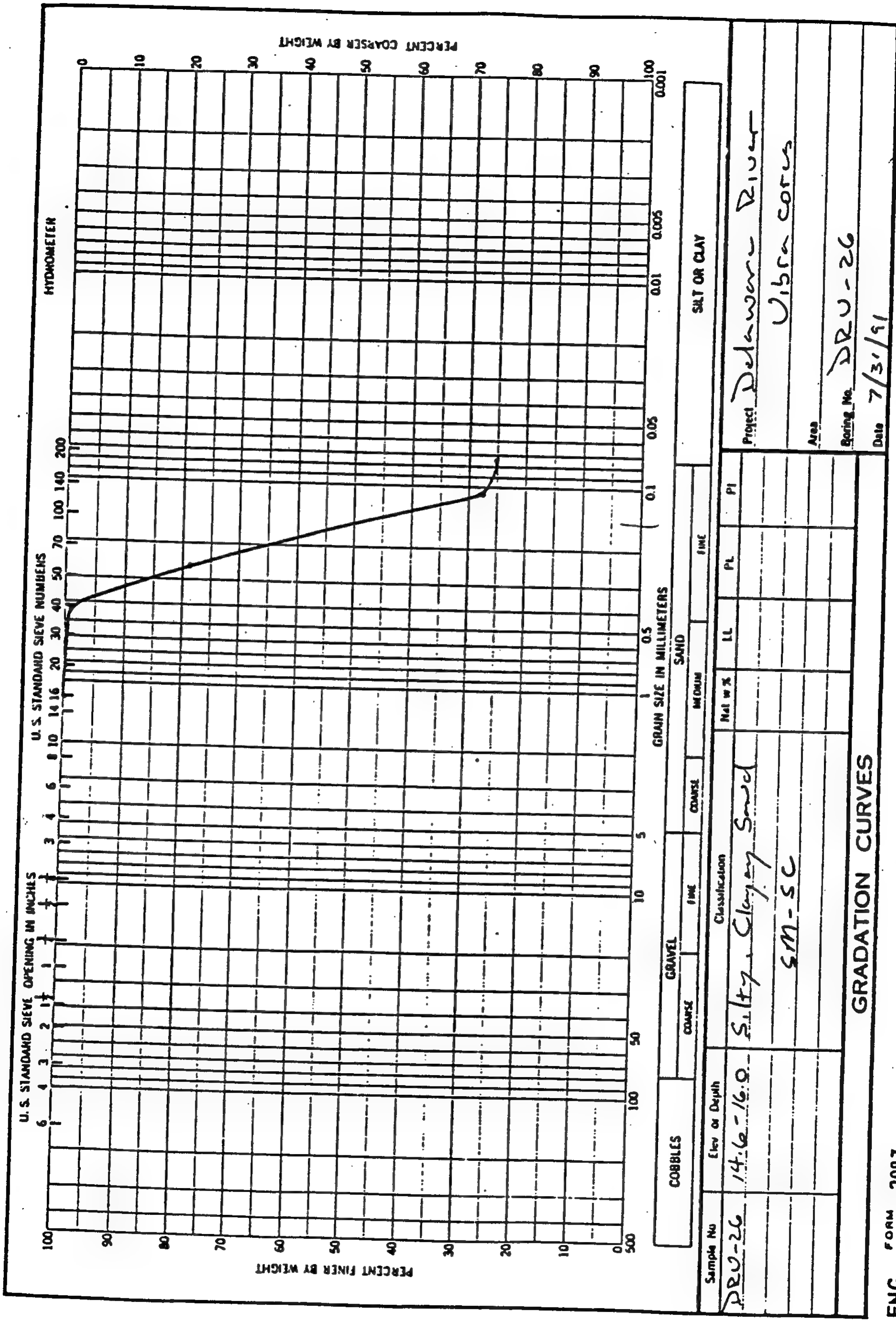


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-26
0.0-5.0
Poorly-Graded Sand
SP
Project Delaware River
Vibracores
Area
Boring No. DRU-26
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRV-26
Elev or Depth 8.3 - 10.0
Classification Poorly - Graded Sand SP
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-26
Date 7/30/91
ENG FORM 1 MAY 63 2087



PERCENT COARSER BY WEIGHT
HYDROMETER
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
DRU-26
Elev or Depth
12.0-14.6
Classification
Silt
ML
Nat w %
LL
PL
PI
Non-Plastic
Project Delaware River Vibracores
Area
Boring No. DRU-26
Date 8/6/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1½ 1 ¾ ½ ⅜
U.S. STANDARD SIEVE NUMBERS
3 4 6 8 10 14 16 20 30 40 50 70 100 140 200
HYDROMETER
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRV-26
14.6-16.0
Silty, Clayey Sand
SM-SC
Project Delaware River Vibra cores
Area
Boring No. DRV-26
Date 7/31/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

PROJECT
Delaware River Comprehensive Study

2. LOCATION (Coordinates or Station) 38° 55' 35.16" 75° 06' 03.83"

3. DRILLING AGENCY Buchart-Horn, Inc.

4. HOLE NO. (As shown on drawing title and file number) DRV-27

5. NAME OF DRILLER Ocean Survey, Inc.

6. DIRECTION OF HOLE VERTICAL INCLINED ________ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN NA

8. DEPTH DRILLED INTO ROCK NA

9. TOTAL DEPTH OF HOLE 15 ft.

10. SIZE AND TYPE OF BIT Vibracore

11. DATUM FOR ELEVATION SHOWN (TBM or MSL)

12. MANUFACTURER'S DESIGNATION OF DRILL NA

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED

14. TOTAL NUMBER CORE BOXES NA

15. ELEVATION GROUND WATER NA

16. DATE HOLE : STARTED 06/14/91 : COMPLETED 06/14/91

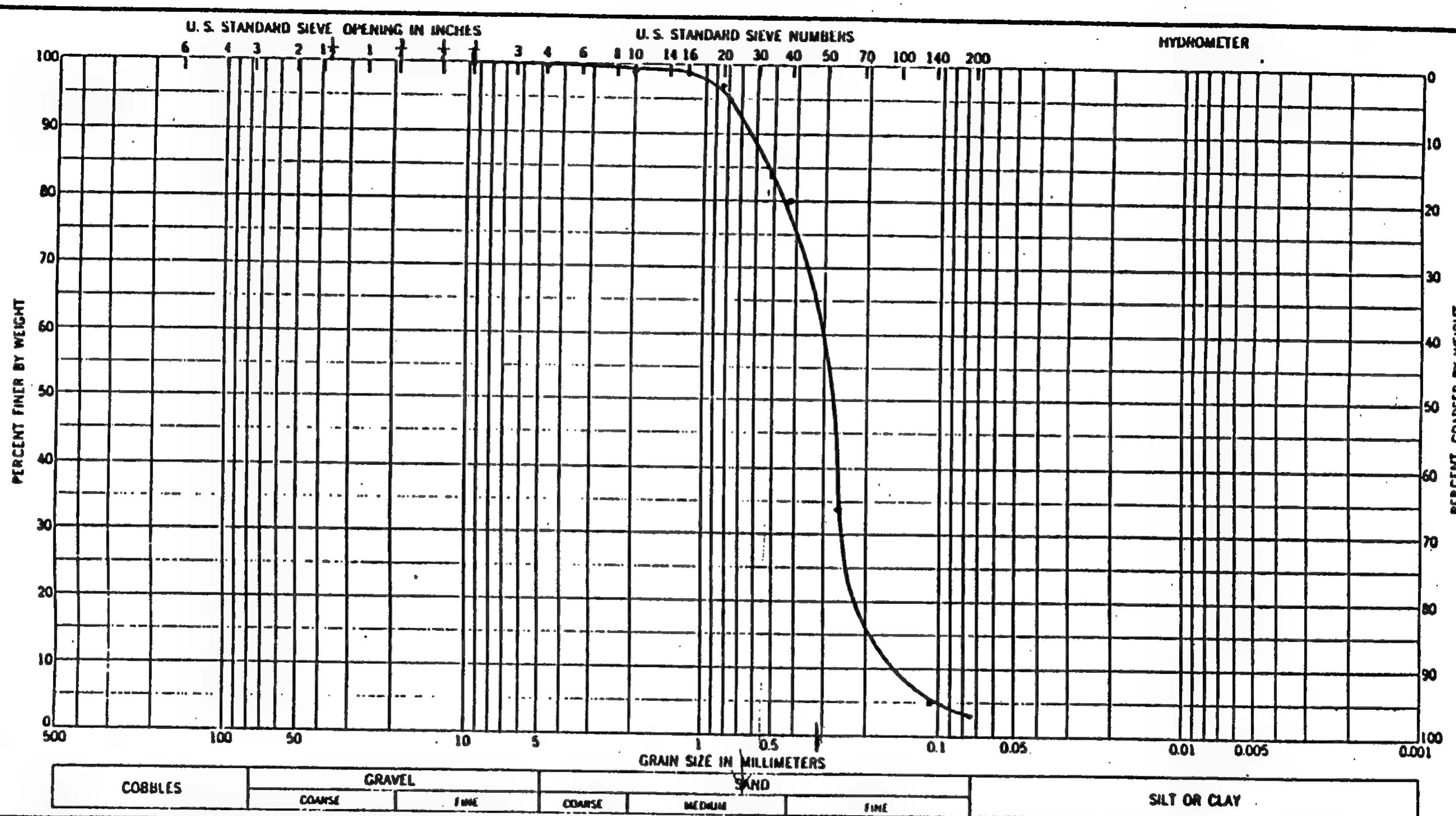
17. ELEVATION TOP OF HOLE -46.5 ft. NGVD

18. TOTAL CORE RECOVERY FOR BORING 15.9/3.9 ft.

19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Brown medium to fine sand SP			One jet retry; Sample 0 - .8 ft.
	.8		Interbedded brown sand with grey sand			
	1.7		Grey sandy with some shells SP			Sample 1.8 - 5.0 ft.
	5		Grey sandy silt with shells SM-SC			Sample 7.2 - 10 ft.
	9.8		Grey clay silt to silty clay firm with shells SM-SC			80° dips
	10.6		Interbedded above and below			
	11.3		Brown silty sand SP			Sample 11.3 - 15 ft.
	15		White sand fine, loose SP			Sample 15 - 16.5 ft.
	16.5		Yellow brown fine sand firm some interbedded white SP			Sample 16.4 - 18 ft.
	18					Bottom of recovery

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-27



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-27	0.0 - 8.0	Poorly-Graded Sand SP				

Project: Delaware River Vibracores

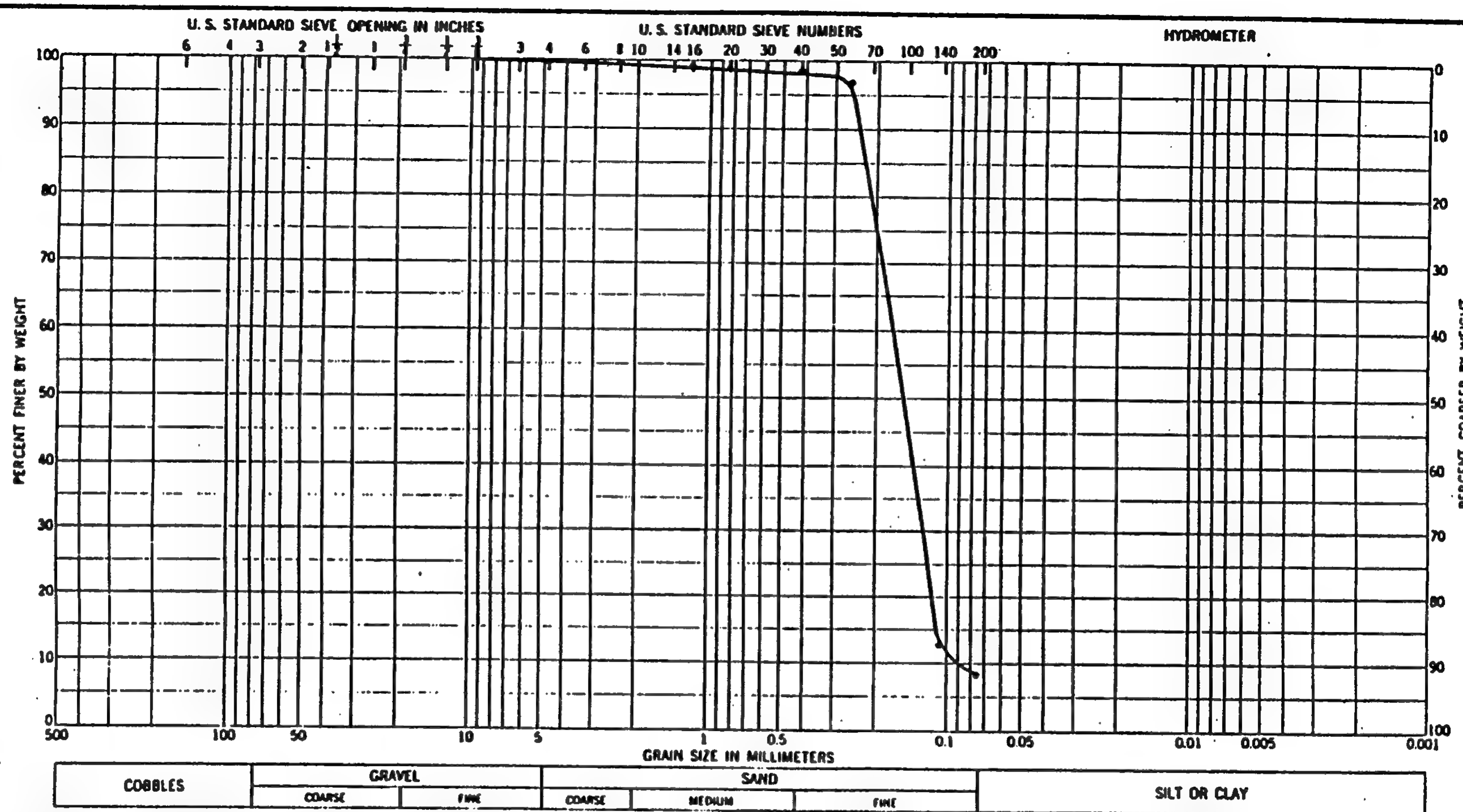
Area:

Boring No. DRU-27

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-27	1.8-5.0	Poorly-Graded Sand				
		SP				

Project: Delaware River Vibracores

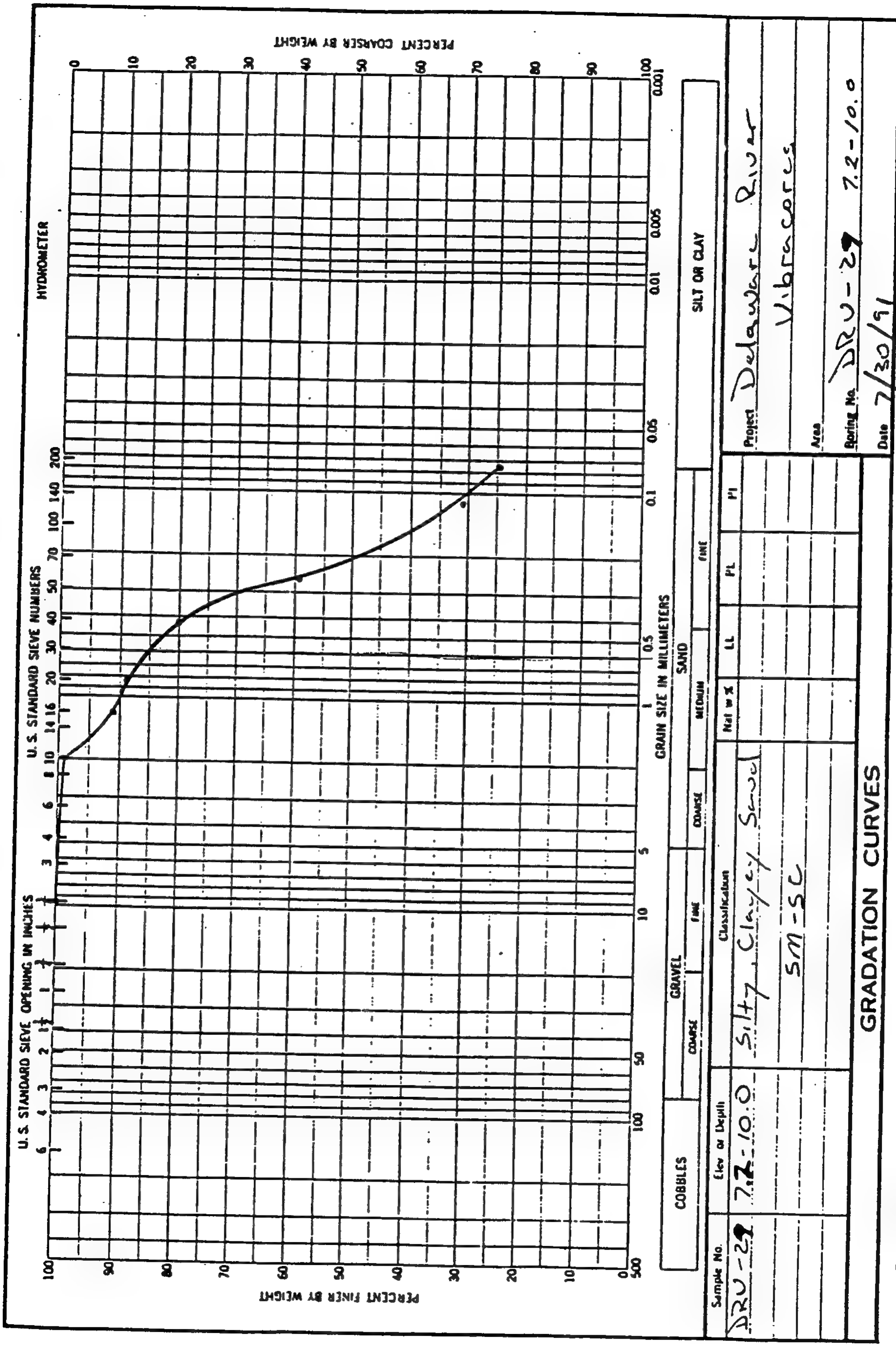
Area:

Boring No. DRU-27

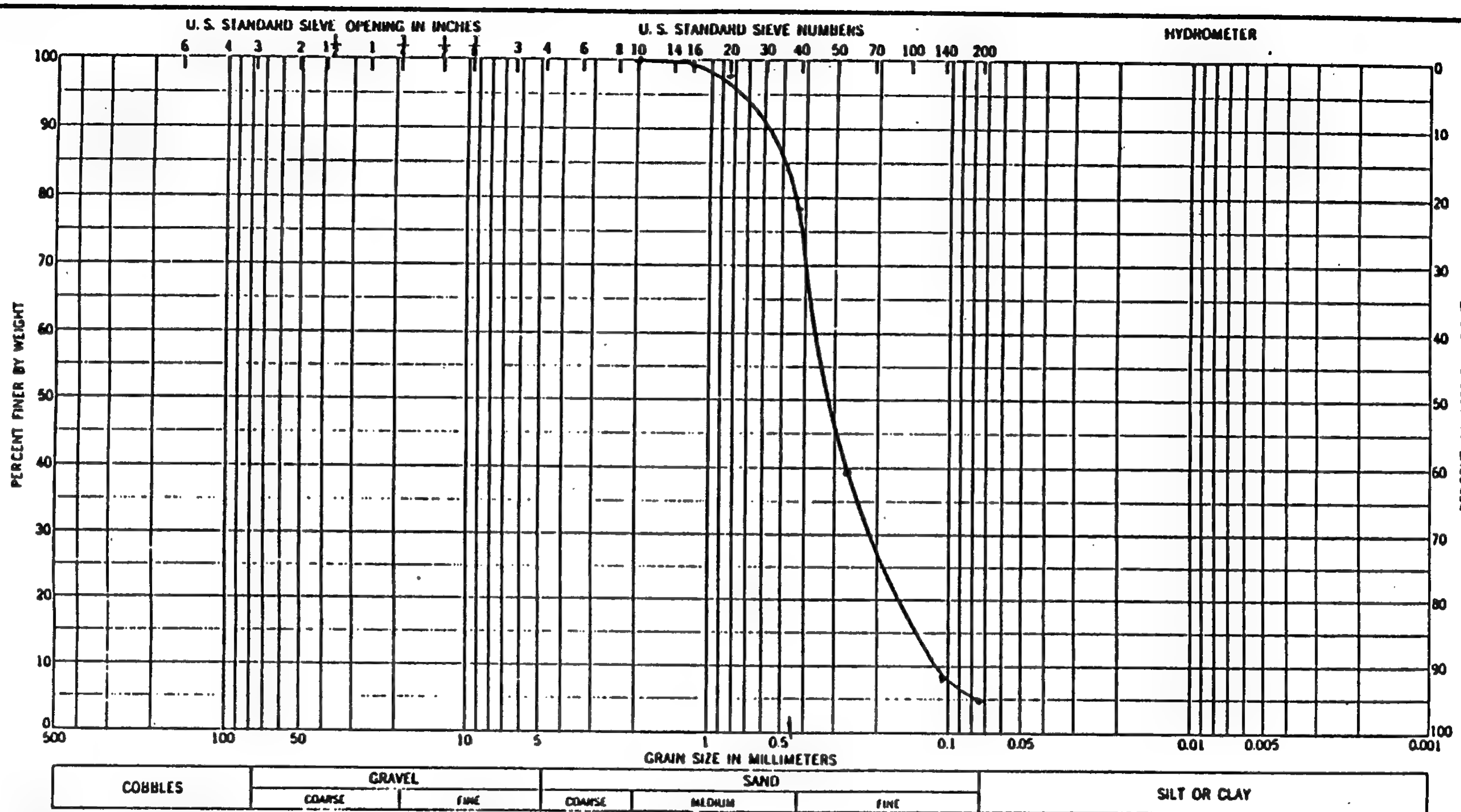
Date 8/6/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRU-29
Elev or Depth
7.2-10.0
Classification
Silty, Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-29 7.2-10.0
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-27	11.3-15.0	Poorly-Graded Sand				
		SP				

Project Delaware River Vibracores

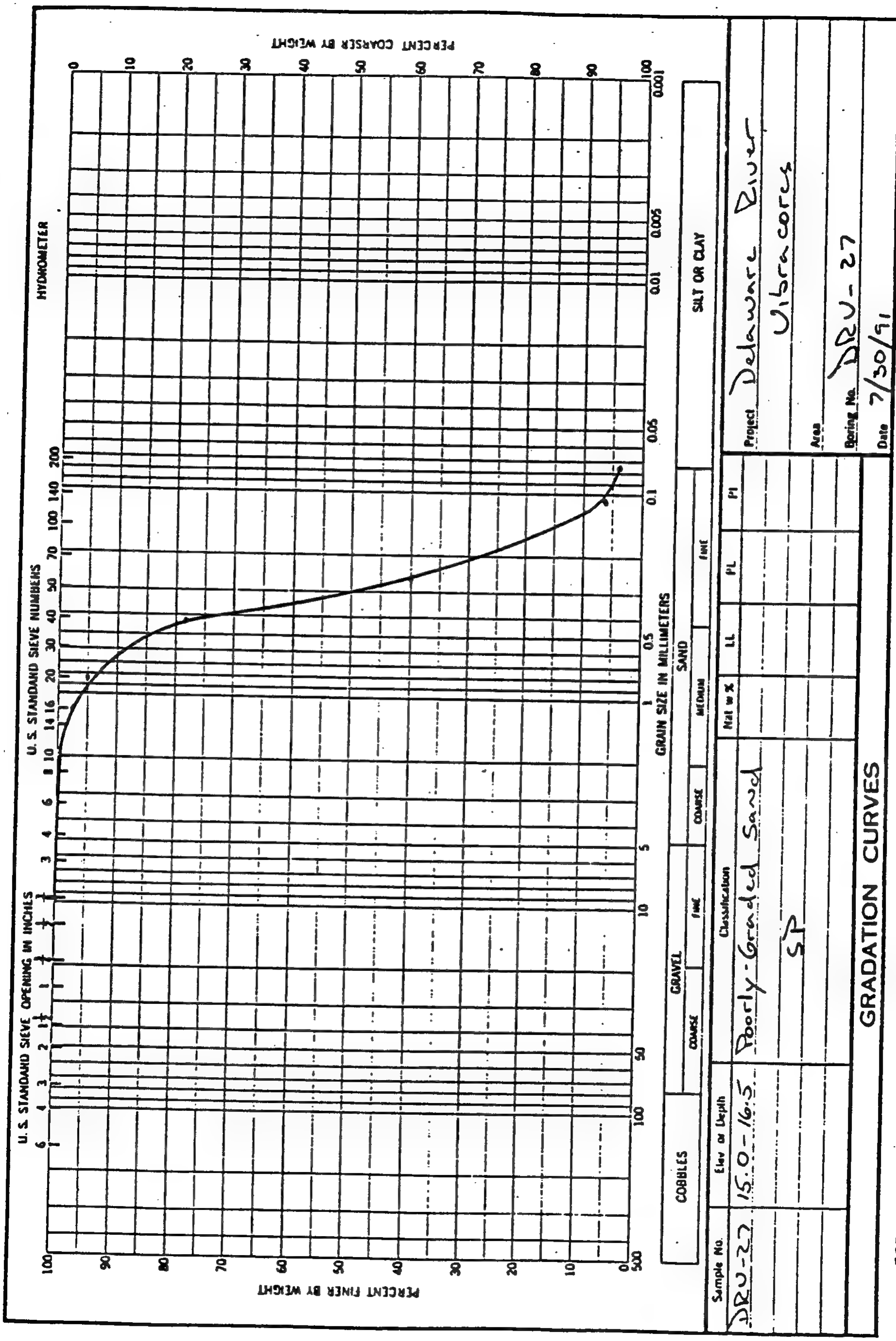
Area

Boring No. DRU-27

Date 7/30/91

GRADATION CURVES

ENG FORM 1 MAY 63 2087



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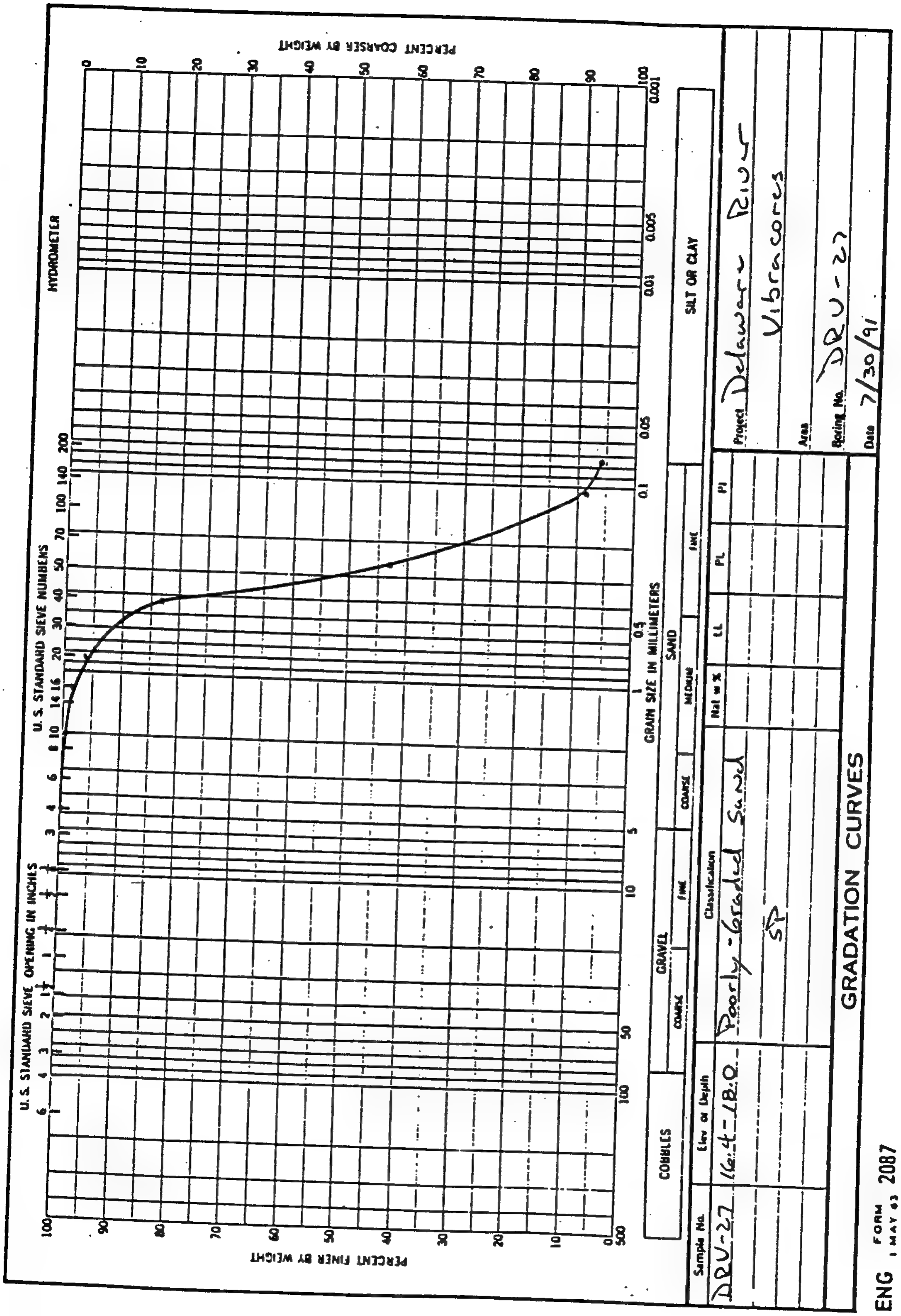
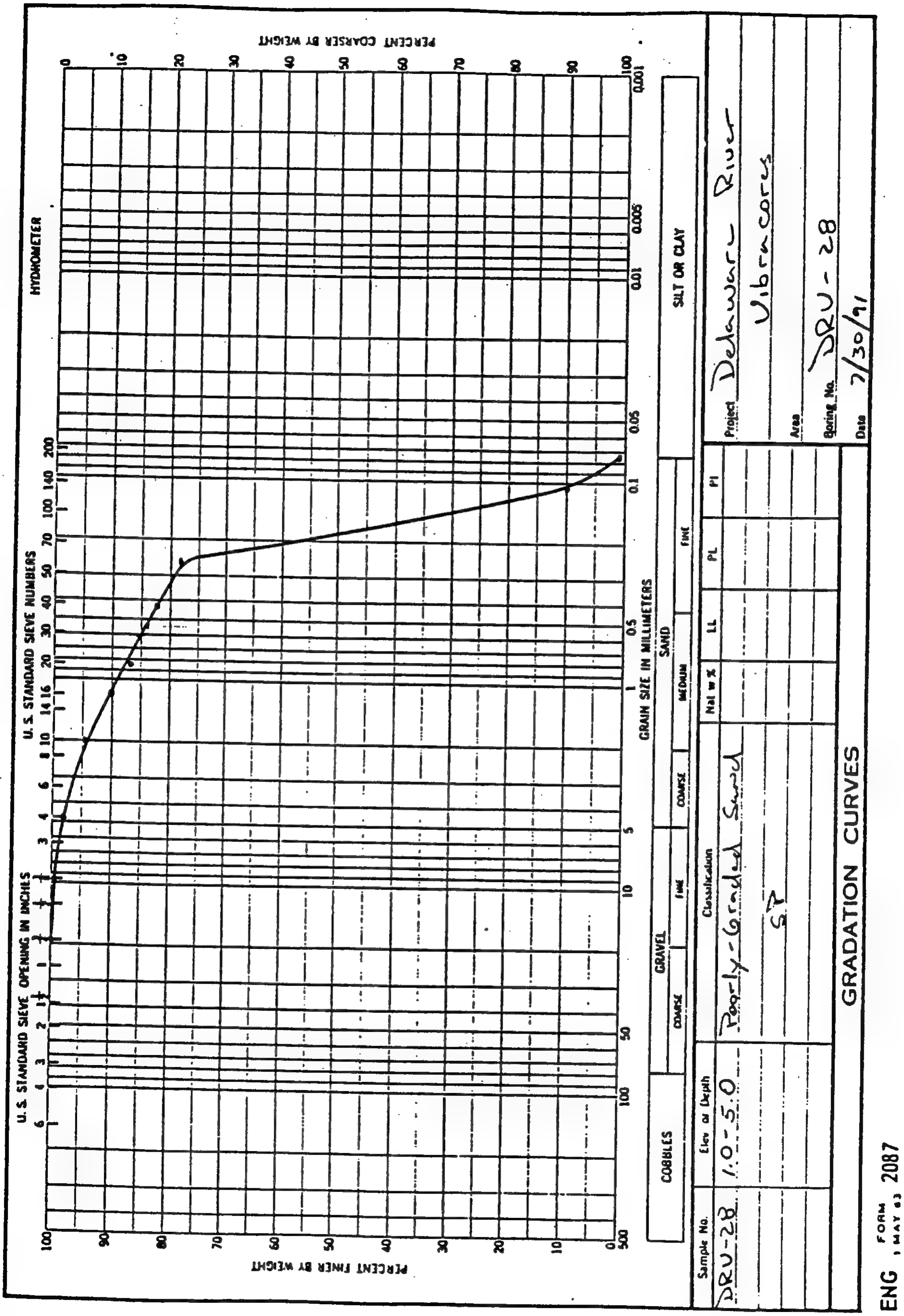
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRV-27
Elev or Depth
15.0-16.5
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-27
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

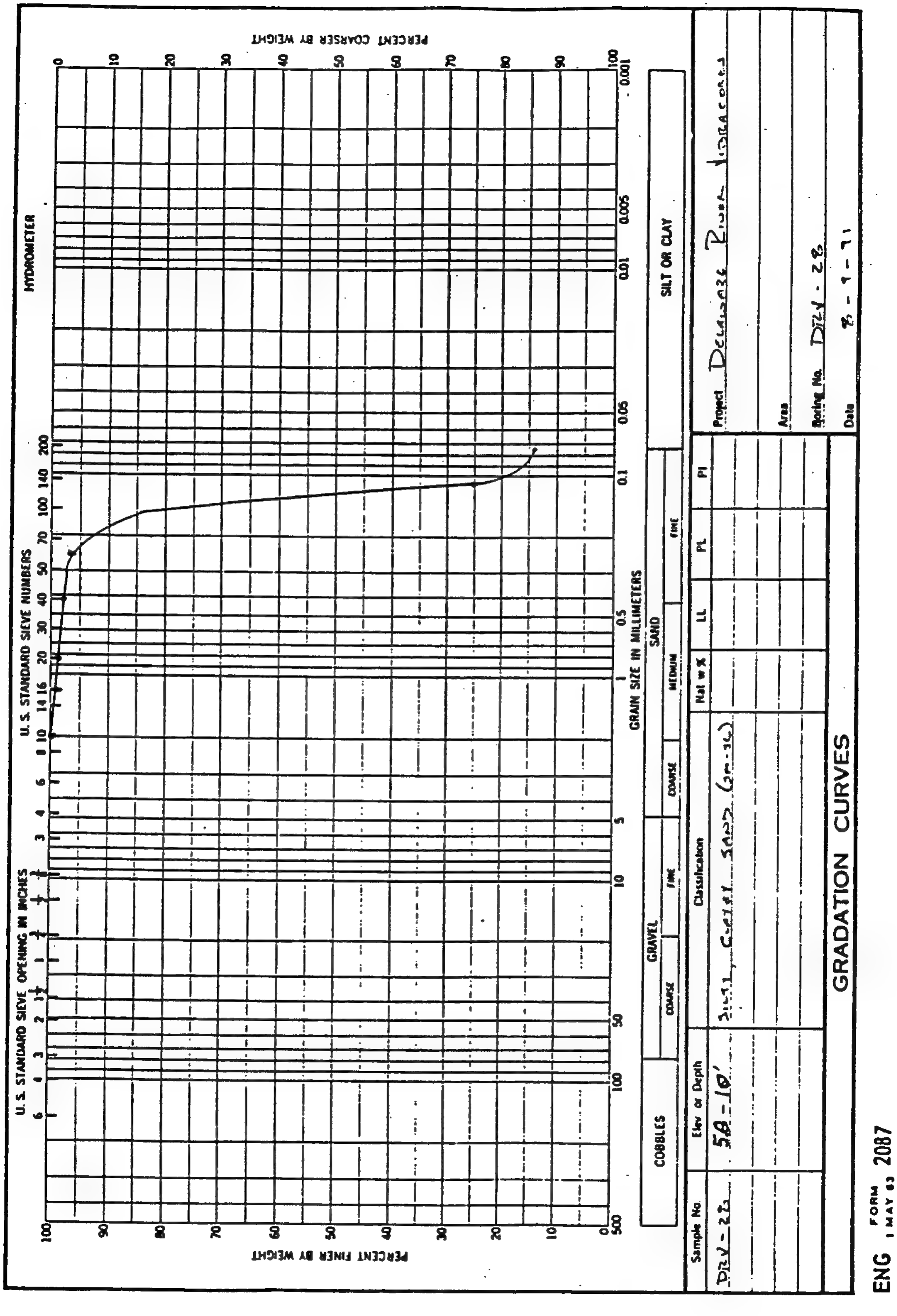

GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRV-27
Elev or Depth 16.4-18.0
Classification Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-27
Date 7/30/91
ENG FORM 1 MAY 63 2087

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS
PROJECT Delaware River Comprehensive Study		10. SIZE AND TYPE OF BIT Vibracore	
		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
2. LOCATION (Coordinates or Station) 38° 54' 16.71" 75° 04' 40.48"		12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore	
3. DRILLING AGENCY Buchart-Horn, Inc.		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED	
4. HOLE NO. (As shown on drawing title and file number)	DRV-28	14. TOTAL NUMBER CORE BOXES NA	
5. NAME OF DRILLER Ocean Survey, Inc.		15. ELEVATION GROUND WATER NA	
		16. DATE HOLE : STARTED 07/15/91 : COMPLETED 07/15/91	
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.		17. ELEVATION TOP OF HOLE -48.6 ft. NGVD	
7. THICKNESS OF OVERBURDEN NA		18. TOTAL CORE RECOVERY FOR BORING 16.5 ft.	
8. DEPTH DRILLED INTO ROCK NA		19. SIGNATURE OF INSPECTOR	
9. TOTAL DEPTH OF HOLE 18 ft.			

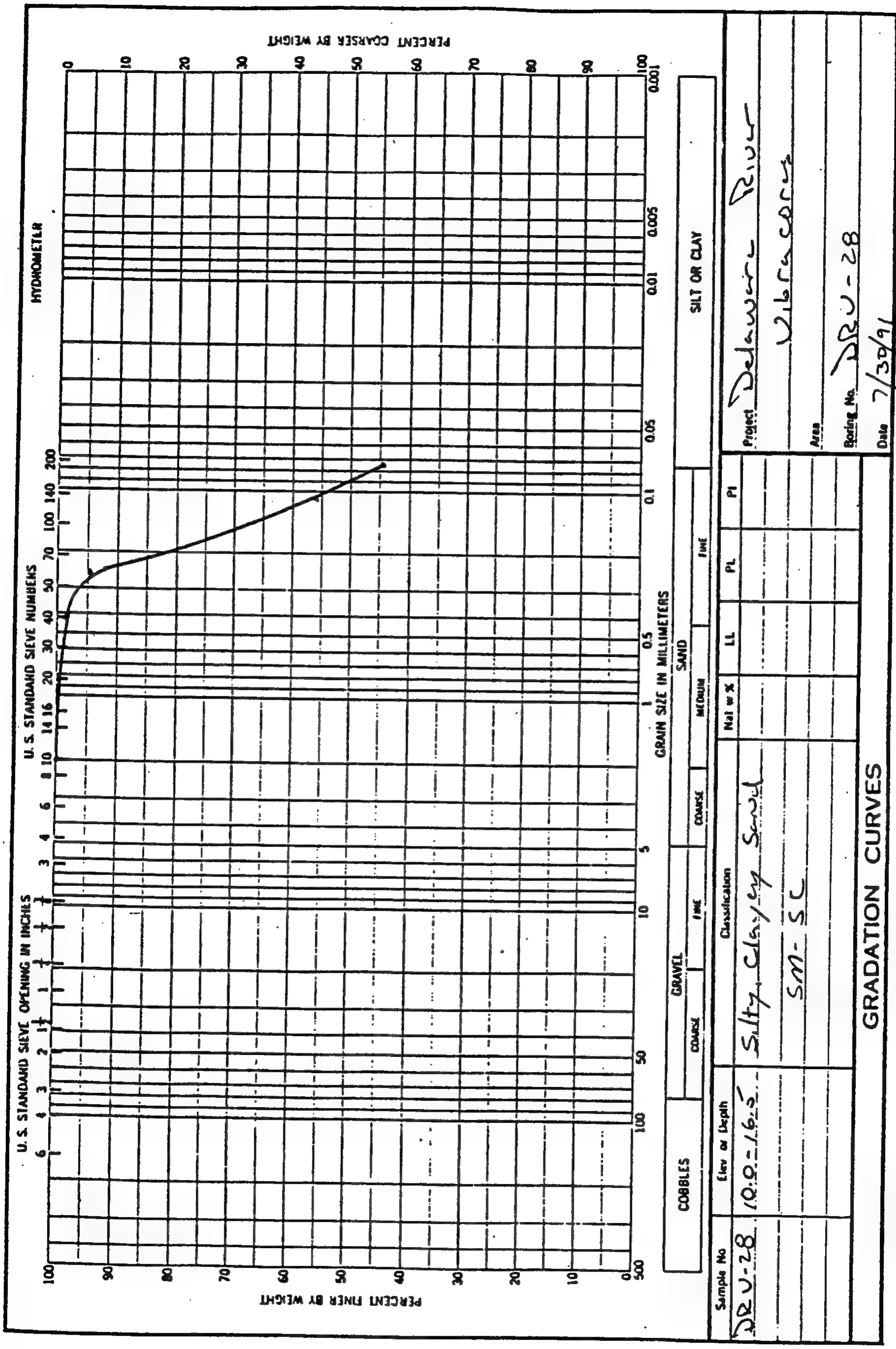
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant g
	0		Grey silt sand			
	1					
	2					Sample 1.0 to 5.0 ft.
	3					
	4					
	5					
	6					Sample 5 - 10 f.t
	7					
	8					
	9					
	10					
	11					Sample 10 - 16.5 ft.
	12					
	13					
	14					
	15					
	16					
	16.5					Bottom of recovery
	17					
	18					
	19					

PROJECT Delaware River Comprehensive Study — HOLE NO. DRV-28


PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRU-28
Elev or Depth
1.0-5.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-28
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRV-28
Elev or Depth
10.0-16.5'
Classification
Silty Clayey Sand
SM-SC
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRV-28
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087

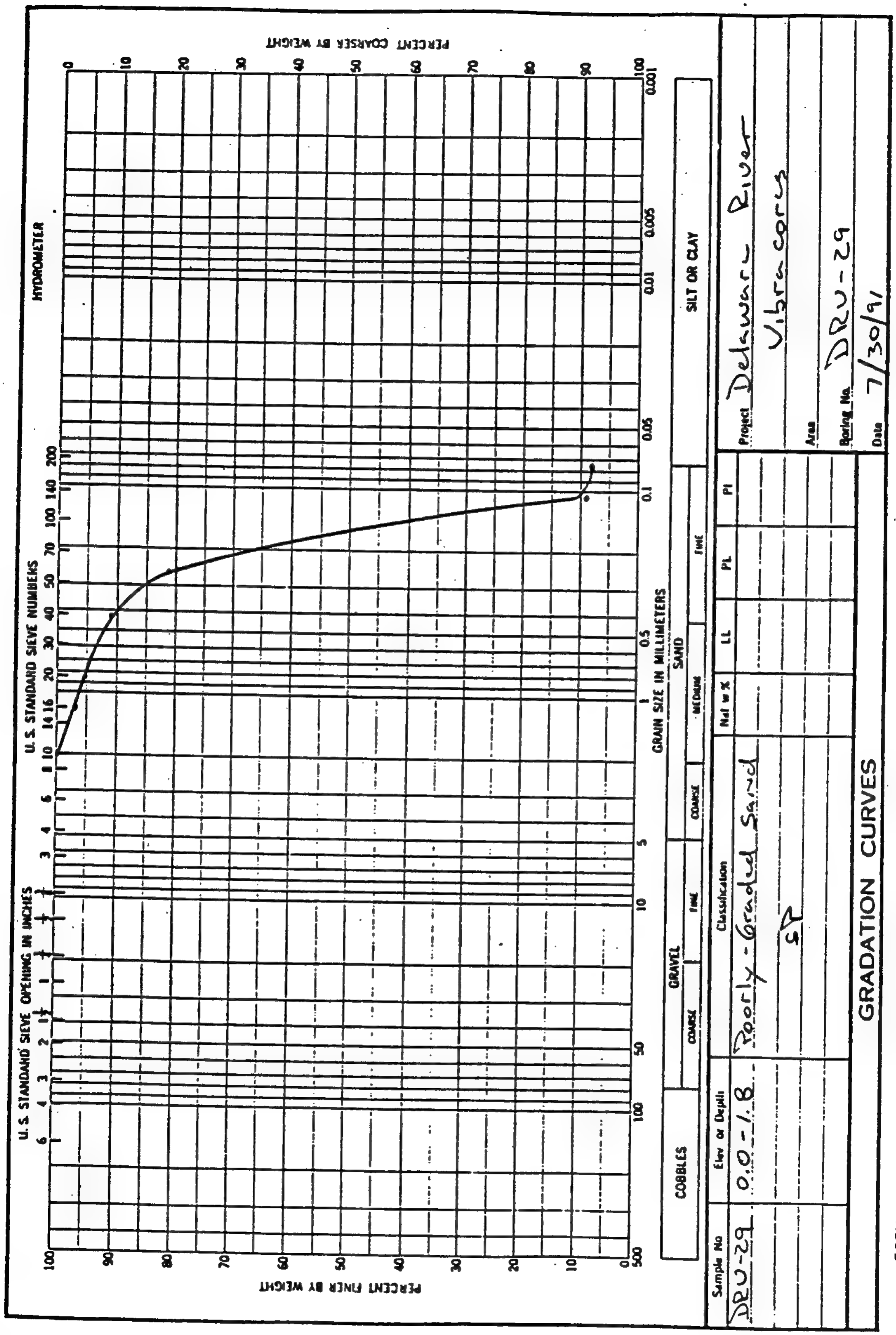
Hole No. DRV-29

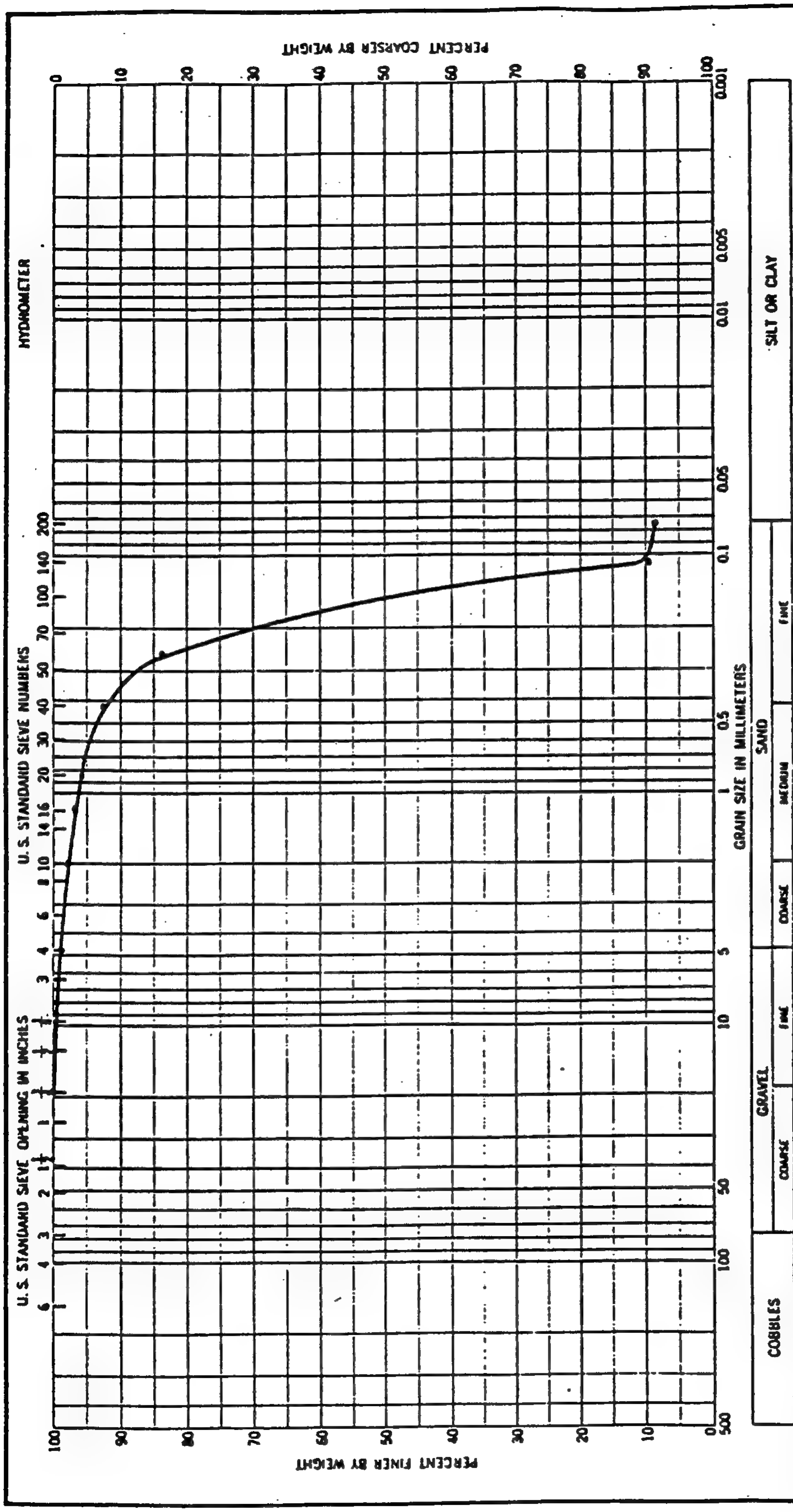
DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Delaware River Comprehensive Study		10. SIZE AND TYPE OF BIT Vibracore	
2. LOCATION (Coordinates or Station) 38° 51' 50.89" 75° 03' 48.42"		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY Buchart-Horn, Inc.		12. MANUFACTURER'S DESIGNATION OF DRILL NA	
4. HOLE NO. (As shown on drawing title and file number)	DRV-29	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN : DISTURBED : UNDISTURBED	
5. NAME OF DRILLER Ocean Survey, Inc.		14. TOTAL NUMBER CORE BOXES NA	
6. DIRECTION OF HOLE VERTICAL INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER NA	
7. THICKNESS OF OVERBURDEN NA		16. DATE HOLE : STARTED 06/14/91 : COMPLETED 06/14/91	
8. DEPTH DRILLED INTO ROCK NA		17. ELEVATION TOP OF HOLE -49.0 ft. NGVD	
9. TOTAL DEPTH OF HOLE 20 ft.		18. TOTAL CORE RECOVERY FOR BORING 19.6 ft.	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Interbedded brown and black silty sand with few shells			Sample 0 - 1.8 ft.
	1.8		Black sand with shells			Sample 1.9 - 5.0 ft.
	5		Trace of clay - black sand with shells		C'	
	7.7		Brown sandy silt with few shells			Sample 7.7 - 10 ft.
	10.4		Black silty sand with concentrations of shell at 10.5, 12.7, 14.8			Sample 10.4 - 15 ft.
	15		Black sand with shell concentrations at 15.8 through 16.2 Scattered shells below 16.2			Sample 15 - 20 ft.

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

PROJECT Delaware River Comprehensive Study | HOLE NO. DRV-29


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No
Elev or Depth
Classification
Nat w %
LL
PL
PI
DRU-29
0.0-1.8
Poorly-Graded Sand
SP
Project Delaware River
Vibracores
Area
Boring No. DRU-29
Date 7/30/91
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
DRU-29	1.9-5.0	Poorly-Graded Sand SP				

Project Delaware River Vibracores

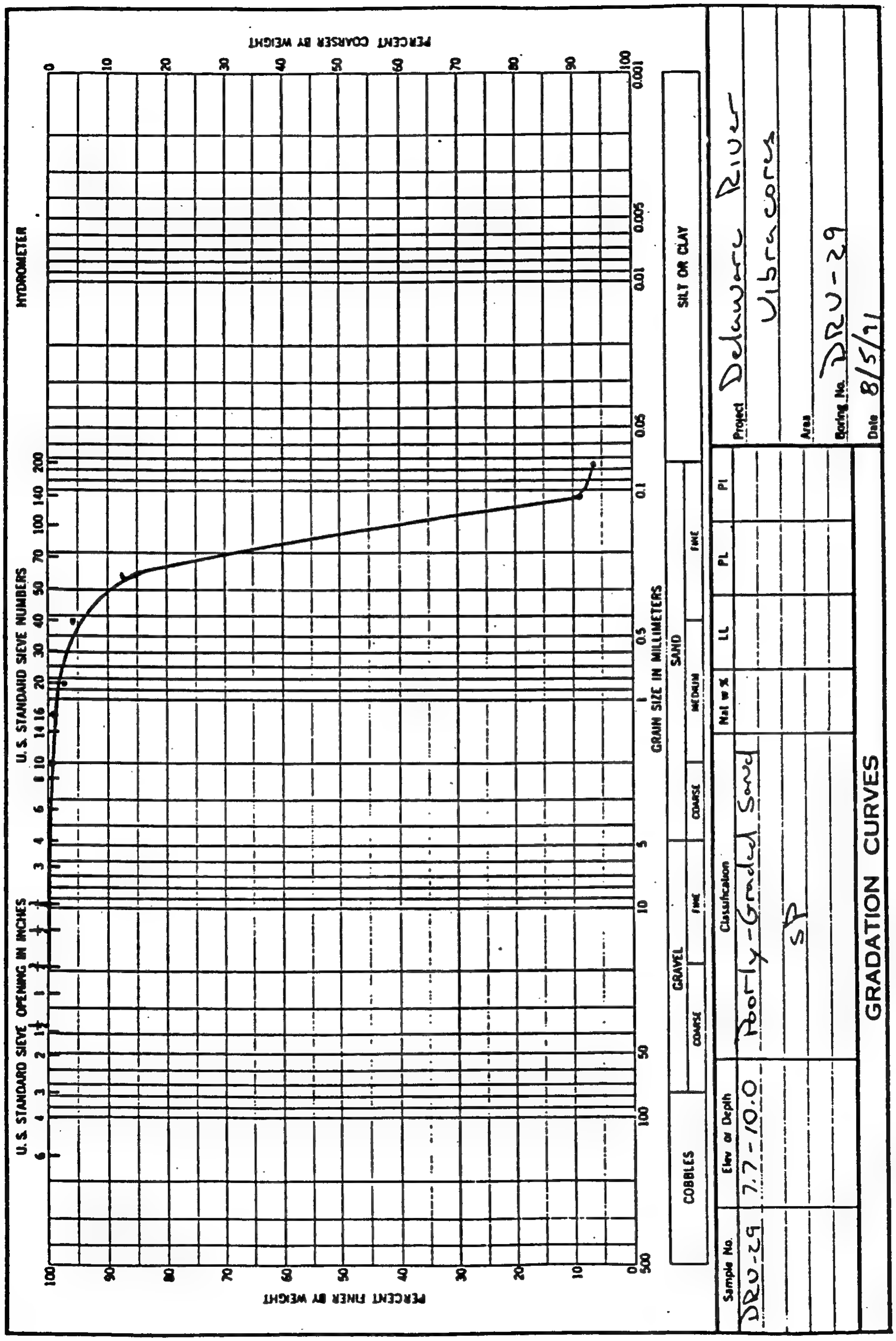
Area

Boring No. DRU-29

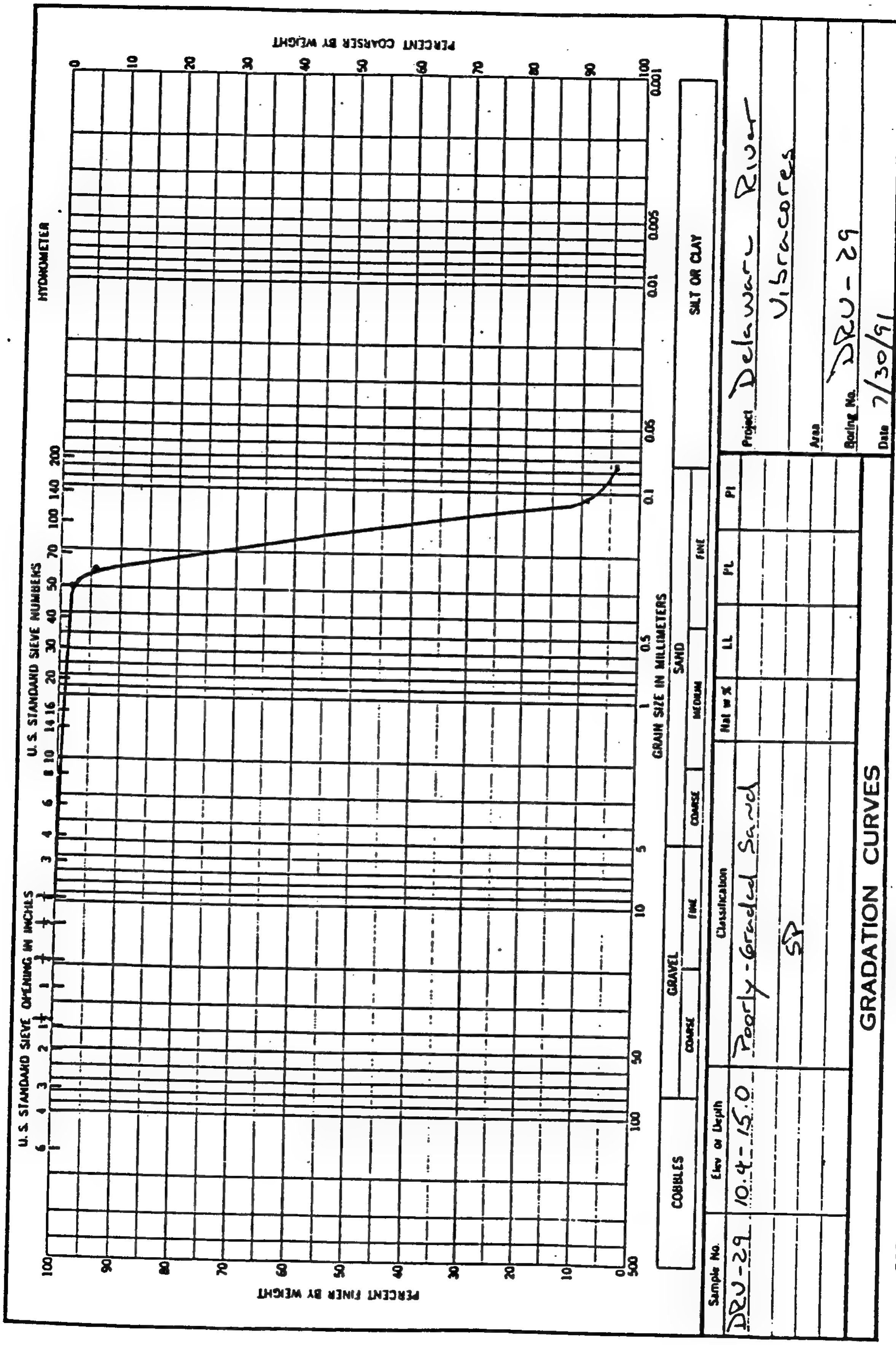
Date 7/30/91

GRADATION CURVES

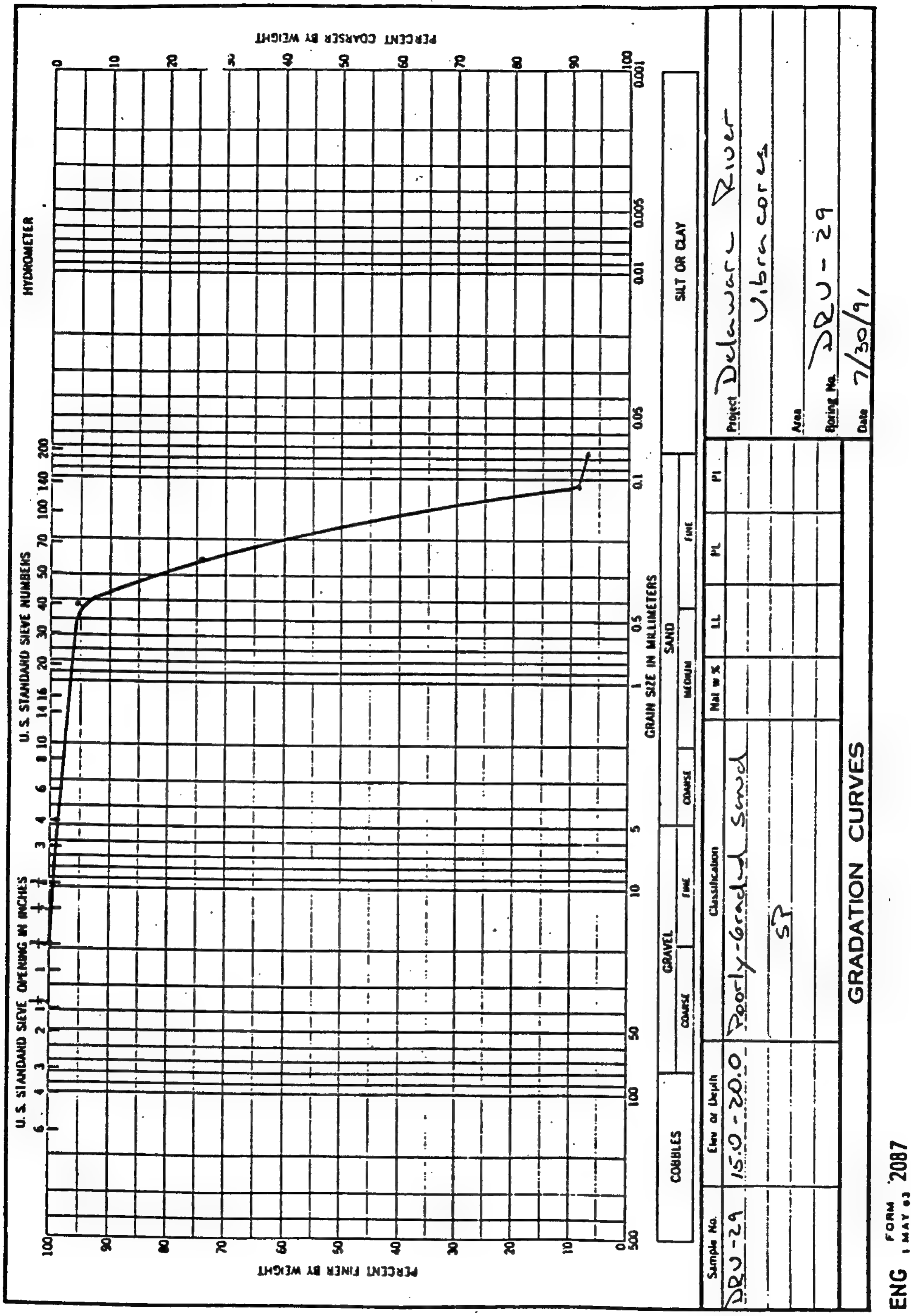
ENG FORM 1 MAY 63 2087



ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. DRV-29
Elev or Depth 10.4-15.0
Classification Poorly-Graded Sand SP
Nat w %
LL
PL
PI
Project Delaware River Vibracores
Area
Boring No. DRV-29
Date 7/30/91
ENG FORM 1 MAY 63 2087


GRADATION CURVES
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
DRU-29
Elev or Depth
15.0-20.0
Classification
Poorly-Graded Sand
SP
Nat w %
LL
PL
PI
Project Delaware River
Vibracores
Area
Boring No. DRU-29
Date 7/30/91
ENG FORM 1 MAY 63 2087

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
DELAWARE R. - REEDY POINT ANCHORAGE	No. 43	41
REEDY ISLAND RANGE	BY J. KOSTURKO	DATE 1/16/63

☐ BORING	☒ TEST PIT	NO. 463
LOCATION Sta. 293+640 790'W ℄		
DATE MADE 1/16/63	BY J. KOSTURKO	
PLANT USED DERRICK BOAT #37		

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0	5 mins	clamshell bucket					Water
							BOTTOM SOUNDING -50.7
50.7			1			GM	Light grey, soft silt and brown, coarse, sand & greyish med. fine gravel (-50.7 to -54.7)
54.7							BOTTOM of PIT, -54.7

42-39 3932 N

✓

NADP FORM 1104 (3-19)
1 SEP 60

TD 462

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
DELAWARE R. - REEDY PT. ANCHORAGE	No. 43	49
REEDY ISLAND RANGE	BY J. KOSTURKO	DATE 1/22/63

☐ BORING ☒ TEST PIT — NO. 461

LOCATION: Sta. 241+680 640'W ℄

DATE MADE: 1/22/63 — BY: J. KOSTURKO

PLANT USED: DERRICK BOAT #37

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0	5 mins.	clamshell bucket					Water
49							Bottom Sounding - 49.0
49.4						SP	Coarse gravel on river bed
50.4			1				Dark grey, med. firm silt with very fine sand. (49.4 to -52.5)
52.5			2			ML	BOTTOM OF PIT -52.5
						OL	Dark gray, firmer silt with some layers of organic matter. (below -52.5)

NADP FORM 1104 (3-19)
1 SEP 60

TPALI

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
DELAWARE R. - REEDY PT. ANCHORAGE	NO. 43	45
REEDY ISLAND RANGE	BY J. KOSTURKO	DATE 1/17/63

☐ BORING ☒ TEST PIT	NO. 459
LOCATION Sta. 239+700 700'W ℄	
DATE MADE 1/17/63	BY J. KOSTURKO
PLANT USED Derrick Boat #37	

Columns: Drilling/Excavating Time | Type penetration | Sample No. | Blows/ft. on sampler lb.hammer w/ in. drop | Core barrel run no. and percent core recovery. | Graphic legend | MATERIALS DESCRIPTION

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Graphic legend	MATERIALS DESCRIPTION
0					Water
40.6	7 mins.	Clamshell bucket			BOTTOM SOUNDING -40.6
41.1			1	ML	Dark grey layered silt with some coarse sand. (-40.6 to 48.4)
48.4			2	GM	BOTTOM of PIT, -48.4 Dark grey layered silt and gray coarse sand & gravel. (Below -48.4)

93,430 E 397,020 N

NADP FORM 1104 (3-19)
1 SEP 60

TI 459

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River; Phila to Sea	73	1
Aquifer Studies – New Castle Range	BY R.GL	DATE 4-5-65

☐ BORING	☒ TEST PIT	NO. DSP1
LOCATION Sta: 233+680 480' W of ℄		
DATE MADE 3-22-65	BY CofE	
PLANT USED Derrickboat #34		

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0							
-40							Water -41.5'
	15 Minutes	3/4 cy clamshell bucket	1			SM and OL	Silty fine to med SAND stratified w/dk-gry org. clayey SILT, some org. matter, soft (-41.5 to -45.3)
-45			2				Predominantly dk-gry clayey SILT w/ v.thin layers of gry v.fine SAND Getting firmer w/depth.
-50						OL	
-55							
-60			3				Bottom of TP - 60.8'

412120 N
92180 E

NADP FORM 1104 (3-19)
1 SEP 60

DSP-1

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River - Phila to Sea	73	1
Aquifer Studies - New Castle Range	BY R.L.	DATE 4-5-65

☐ BORING ☒ TEST PIT	NO. DSP2
LOCATION Sta. 231+900 530' W of ℄	
DATE MADE 3-22-65	BY C of E
PLANT USED DB#37	

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
35							Water - 37.2
40	40 Minutes	3/4 CY Clamshell bucket	1			SM and OL	Silty finetomed SAND stratified w/ v. soft dk-gry organic SILT. (37.2 - 47.6)
45–55			2			OL	Interlayered gry v. fine silty sand & dk-gry org. silty CLAY, slightly firm & plastic Sandy layers v. thin. Getting firmer w/ depth. (-47.6 - 60.2')
60			3				Bottom of TP - 60.2'

403240 //
71 20 5

NADP FORM 1 SEP 60 1104 (3-19)

DSP 2

BORING/TEST PIT LOG

PROJECT Delaware River Phila to Sea	FIELD BOOK 73	PAGE 2
Aquifer Studies - New Castle	BY R.L	DATE 4-5-65

BORING	☒ TEST PIT	NO. DSP-3
LOCATION Sta. 229+840 460' W of ℄		
DATE MADE 3-22-65	BY CofE	
PLANT USED DB#37		

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
39							Water - 39.6'
40	45 Minutes	3/4 cy clamshell bucket	1			SM and OL	Interbedded org. clayey SILT, dk-gry in color w/ fine sand, Some org. matter V. soft. (39.6' - 44.9')
45						OL	Dk-gry silty org. CLAY, fairly firm interbedded w/ v. thin layers of gry v. fine sand (44.9' - 60.1)
50							
55							
60			2				Bottom of TP - 60.1'

405,580 N
90490 E

NADP FORM 1 SEP 60 1104 (3-19)

DSP-3

BORING/TEST PIT LOG

PROJECT Delaware River - Phila to Sea	FIELD BOOK 73	PAGE 2
New Castle Range	BY R.L	DATE 4-5-65

☐ BORING	☒ TEST PIT	NO. DSP4	
LOCATION Sta. 228+960 520' E ℄			
DATE MADE 3-23-65	BY CofE		
PLANT USED DB # 37			

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
							Water - 37.6'
37							
	55 Minutes	3/4 cy clamshell bucket	1			SP	
40							Brn med to coarse SAND (veneer) underlain by org. silty CLAY w/ thin layers of fine gry sand.
						OL	
45							
			2				Same w/ occ sand layers
50			3			SP	Sand, gry, fine to med grained, hard & dense (50.3')
							Bottom of TP - 50.3'

NADP FORM 1104 (3-19)
1 SEP 60

DSP-4

BORING/TEST PIT LOG

PROJECT Delaware River Phila to Sea	FIELD BOOK 73	PAGE 3
Aquifer Studies	BY R.L	DATE 4-5-65

BORING	TEST PIT (X)	NO. DSP5
LOCATION Sta. 219+800 610' W of ℄		
DATE MADE 3-23-65	BY C of E	
PLANT USED DB #37		

Water 44°F

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
37							Water -37.2
	35 Min.		1				
40			2			SP	Sand & GRAVEL, subrounded up to 1" in size w/ occ. cobbles. Some org. dk-gry silt
							Bottom of TP -40.3'

NADP FORM 1 SEP 60 1104 (3-19)

DSP5

BORING/TEST PIT LOG

PROJECT WILMINGTON HARBOR South Delaware River (Phila to Sea	FIELD BOOK	PAGE 1 OF 1
	BY DLT/SAK	DATE 12-15-86

BORING	☒ TEST PIT	NO. 44 DFP
LOCATION Sta. 219+000 200' W of ℄		
DATE MADE 12-13-86	BY COE	
PLANT USED TITAN		

COE DELAWARE R. DATUM (FT)

Elevation	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ - in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						Water
-45.6	44	Clamshell Bucket	1			SP-SM	Brn, Silty, Sandy GRAVEL w/occ Cobble (45.6 to 46.4)
-46.4			2			ML	Gry brn CLayey SILT. Stiff. Difficult digging (-46.4 to -47.4)
-49.7			3			GP	Brn. C-F sandy GRAVEL. Predominately coarse w/some Cobbles (-47.4 to -50.7)
-50.7							Bottom of Test Pit -50.7

NADP FORM 1104 (3-19)

BORING/TEST PIT LOG

PROJECT WILMINGTON HARBOR SOUTH	FIELD BOOK	PAGE 1 OF 1
DELAWARE RIVER (Phila to Sea)	BY DLT/SAK	DATE 12-15-86

COE DELAWARE & DATUM (FT)

BORING / ☒ TEST PIT	NO. 45 DFP
LOCATION Sta. 219+000 200' E of ℄	
DATE MADE 12-13-86	BY COE
PLANT USED TITAN	

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						Water
-46.6	48	Clamshell Bucket	1			GP GM	Brn. C-F GRAVEL, predominately Coarse w/some sand ± Tr c/Silt. Occ Cobble to 1/2 Becomes sandier w/depth and increase in Cobbles; silt becoming muddy brown (46.6 to 52.0)
-52.0			2			SP	Brn m-f SAND w/some gravel and few Cobbles and Boulder. (52.0 to 55.1)
-55.1							Bottom of Test Pit - 55.1

NADP FORM 1104 (5-79)

BORING/TEST PIT LOG

PROJECT WILMINGTON HABOR SOUTH	FIELD BOOK	PAGE 1 OF 1
Delaware River (Phila to Sea)	BY DLT/SAK	DATE 12-15-86

BORING	TEST PIT	NO. 73 OFP
LOCATION Sta. 217+000 200' W of ℄		
DATE MADE 12-13-86	BY COE	
PLANT USED TITAN		

JOE DELAWARE R. DATUM (FT)

Elevation	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						Water
-44.8	50	Clamshell Bkt.	1			GP GM	Brn. C-F GRAVEL w/some sand & Trace of silt some cobbles. Becomes sandier w/depth and occ. Cobbles & Boulder noted (-44.8 to 49.4)
-50.0 / -50.4			2			ML	Yellow brn. clayey SILT w/pkts of med gry micaceous clayey silt (-49.4 to -50.4)
							Bottom of Test Pit -50.4

Note:
- Difficult Digging 49.4 to bottom

NADP FORM 1104 (3-19)

BORING/TEST PIT LOG

PROJECT Wilmington Hbr. South	FIELD BOOK	PAGE 1 OF 1
Delaware River (Phila to Sea)	BY SAK/DLT	DATE 12-13-86

☐ BORING	☒ TEST PIT	NO. 36 DFP
LOCATION Sta. 212+000 400' E of ℄		
DATE MADE 12-11-86	BY COE	
PLANT USED TITAN		

COE DELAWARE R. DATUM (FT)

Elevation	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0.0 to -45.5	minutes						Water.
-45.5	25	Clamshell bucket		1		SP	SAND c Gravel c-f, several cobbles (-45.5 to 46.5)
				2		Pt	Peat, silty, clayey (-46.5 to -48.7)
-48.7	15			3		SP	SAND, c-f, med. gry, w/ some cobbles (-48.7' to -50.1)
-50.1				4		SM	SAND, silty, c-f, rare cobbles & boulders (-50.1 to -51.5)
-51.5	55					SM	SAND, silty, m-f, yel. brn w/ occ. gravel and cobbles (-51.5 to -56.5)
-55.0							
-56.5				5			Bottom of Test Pit -56.5

NADP FORM 1104 (1-19)

PROJECT Wilmington Hbr. South.	FIELD BOOK	PAGE 1 OF 1
Delaware River (Phila to Sea)	BY SAK/DLT	DATE 12-15-86

BORING	TEST PIT ☒	NO. 35 DFP
LOCATION Sta. 210+500 400' E of ¢		
DATE MADE 12-11-86	BY COE	
PLANT USED Titan		

COE DELAWARE R. DATUM (FT)

Elevation	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						Water -
-45.3	43	Clamshell Buckets	1			GP	silty, sandy GRAVEL, c-f, dk-gray (-45.3 to -50.0)
-50.0						SP	SAND, c-f, gravelly, med. gray (-50.0 to -55.7)
-55.7			2				Bottom of Test Pit -55.7

NADP FORM 1 SEP 60 1104 (3-19)

BORING/TEST PIT LOG

PROJECT WILMINGTON HARBOR (South) Delaware River (Phila to Sea)	FIELD BOOK	PAGE 1 OF 1
	BY SAK/DLT	DATE 12-15-86

☐ BORING ☒ TEST PIT	NO. 32 DFP
LOCATION Sta. 209+000 450' E of ℄	
DATE MADE 12-10-86	BY COE
PLANT USED TITAN	

COE DELAWARE DATUM (FT)	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0.0							Water
-45.6	2 hrs & 18 minutes	Clamshell Bucket	1			GP/GM	Brn. Sandy GRAVEL w/tr Silt occ. small Cobble (-45.6 to -50.5) Note: Becomes sandier w/depth below 50.5'. (-50.5 to -55.7)
-55.7			2			SP	Red gray gravelly C-F SAND
							Bottom of Test Pit -55.7

NADP FORM 1104 (3-19)

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Wilmington Harbor South		1 OF 1
Delaware River - Philadelphia to Sea	BY DLT/SAK	DATE 12-16-86

☐ BORING ☒ TEST PIT	NO. 31 DFP
LOCATION STA 205+000/200'E	
DATE MADE 12-9-86	BY COE
PLANT USED TITAN	

COE CLEARANCE DATUM, FT	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						
-44.4			1				Water
	30	Bucket				OL	Soft, grey brown, organic SILT w/ Sand partings & some black organics. (-44.4 to -51.1)
-51.1			2			SP & GP	C-f SAND & C-f GRAVEL w/ tr. black silt (-51.1 to -57.5) Note: Becomes sandier w/depth
	1 hr and 3	Clamshell					
-57.5			3			SP	C-f SAND, tr silt, scattered pieces of gr. Bottom of Test Pit -57.5

NADP FORM 1 SEP 60 1104 (3-19)

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Wilmington Harbor South		1 OF 1
Delaware River- Philadelphia to Sea	BY DLT/SAK	DATE 12-16-86

☐ BORING ☒ TEST PIT	NO. 26 DFP
LOCATION STA 200+000/200 E	
DATE MADE 12-6-86	BY COE
PLANT USED TITAN	

COE DELAWARE R. DATUM (FT)	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0.0	minutes						Water
-42.8	27	Clam shell Bucket	1			ML	Dk grey; soft, clayey SILT (-42.8 to -55.4)
-55.4			2			ML	Dk grey, soft, clayey SILT Bottom of Test Pit -55.4

NADP FORM 1104 (3-19)

BORING/TEST PIT LOG

PROJECT Delaware River - Phila to Sea	FIELD BOOK 73	PAGE 4
Deepwater Point	BY R.L	DATE 4-5-65

BORING	TEST PIT (X)	NO. DSP7
LOCATION Sta: 197+480 500' W of ℄		
DATE MADE 3-24-65	BY CofE	
PLANT USED DB #37		

Water 46°F

Columns: Drilling/Excavating Time | Type penetration | Sample No. | Blows/ft. on sampler - lb. hammer w/ in. drop | Core barrel run no. and percent core recovery | Graphic legend | MATERIALS DESCRIPTION

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Graphic legend	Materials Description
					Water - 37.9'
38			1		
40					
				OL	Dk-gry org SILT very soft, some black layers of silt & clayey silt Tr of sand (37.9 - 42.5)
45					
50	30 Minutes	3/4 cy clamshell bucket	2	OL	Dk-gry silty clay w/v. thin layers of gry v. fine sand (42.5' - 60.9')
55					
60			3		
					Bottom of TP - 60.9'

NADP FORM 1 SEP 60 1104 (3-19)

DSP 7

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Wilmington Harbor South		1 OF 1
Delaware River - Philadelphia to Sea	BY DLT/SAK	DATE 12-16-86

☐ BORING ☒ TEST PIT NO. 25 DFP

LOCATION: STA 195+000/200'E

DATE MADE: 12-6-86 BY: COE

PLANT USED: TITAN

COE DELAWARE R. DATUM (FT)	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0.0							Water
−44.5	19	Clamshell Bucket	1			CL	DK grey silty CLAY, med stiff. (−44.5 to −55.2)
−55.2							Bottom of Test Pit −55.2

NADP FORM 1104 (3-19)

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Wilmington Harbor South		1 OF 1
Delaware River - Philadelphia to Sea	BY DLT/SAK	DATE

BORING [ ] TEST PIT [X] NO. 24 DFP

LOCATION: STA 190+000/200E

DATE MADE: 12-6-86 BY: COE

PLANT USED: TITAN

ELEV. (FT)	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0.0							No tex
-46.5	18	Clamshell Bucket	1			ML	DK grey silty CLAY w/occ. fine sand layers up to 2" thk (-46.5 to -56.6)
-56.6							Bottom of Test Pit -56.6

NADP FORM 1104 (3-10)

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River - Phila to Sea	73	4
Aquifer Studies	BY R.L	DATE 4-5-65

BORING	☒ TEST PIT	NO. DSP-9
LOCATION Sta: 172+030 270' W of ℄		
DATE MADE 3/29/65	BY CofE	
PLANT USED DB # 37		

Water 45°F

Drilling/Excavating Time | Type penetration | Sample No. | Blows/ft. on sampler - lb.hammer w/ in. drop | Core barrel run no. and percent core recovery | Graphic legend | MATERIALS DESCRIPTION

Water - 35.2'

35

1

Dk-gry org. clayey SILT v. soft. Getting firmer @ 40.0'

40

45

2 OL same but firmer w/ thin layers of fine sand

50

35 Minutes

3/4 cy clamshell bucket

55

60

3

Bottom - 60.8

NADP FORM 1 SEP 60 1104 (3-19)

DSP 9

BORING/TEST PIT LOG

PROJECT Del. R., Phila. to Sea	FIELD BOOK TP20	PAGE —
159+700 240' W. ¢ Bellevue R.	BY Reardon	DATE 1/17/62

☐ BORING	☒ TEST PIT	NO. 431
LOCATION Sta. 159+700 240' W. ¢		
DATE MADE 1/17/62	BY Hired Labor	
PLANT USED Derrickboat 37		

Columns: Drilling/Excavating Time; Type penetration; Sample No.; Blows/ft. on sampler; Core bored run no. and percent core recovery; Graphic legend

MATERIALS DESCRIPTION

Drilling/Excavating Time: 1 Hr. 48 Mins.

Type penetration: clamshell bucket

Depth	Sample No.	Materials Description
0		Water
35.2	1	River bottom, - 35.2'
		Dark gray SILT. (35.2 - 38.8)
38.8	2	Reddish-gray, gravelly clayey SAND; some cobbles (38.8 - 40.8)
39.8	3	
40.8	4	Red sandy CLAY; some gravel & cobbles. (40.8 - 42.7)
41.8	5	
42.7	6	~~Stiff, red & gray CLAY~~ (42.7 - 43.7)
	7	Red & gray CLAY with cobbles (43.7 - 44.2)
44.2		Bottom of hole, - 44.2'

106700 E
~~47~~ 8340 N

NADP FORM 1104 (3-19)
1 SEP 60

TP 431

BORING/TEST PIT LOG

PROJECT De. R., Phila to Sea	FIELD BOOK TP2C	PAGE —
Sta 151+920 455' E of ¢	BY Reeraan	DATE 1/19/62

☐ BORING ☒ TEST PIT	NO. 435
LOCATION Sta. 151+920 455'E. ¢	
DATE MADE 1/19/62	BY Hired Labor
PLANT USED Derrickboat 37	

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0							Water
36.2							River bottom, -36.2'
37.6	18 Mins.	Clamshell bucket	1				Soft, dark gray organic SILT & CLAY with occasional fine sandy layers. (36.2 - 50.3)
50.3			2				Bottom of hole, - 50.3'

111540 E
473240 N

NADP FORM 1104 (3-19)
1 SEP 60

TP435

BORING/TEST PIT LOG

PROJECT Del. R., Phila to Sea	FIELD BOOK TP 20	PAGE —
Sta. 149+950 450' W. ℄ Bellevue	BY Reardon	DATE 1/19/62

BORING	X TEST PIT	NO. 437
LOCATION Sta. 149+950 450' W. ℄		
DATE MADE 1/19/62	BY Hired Labor	
PLANT USED Derrickboat 37		

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
0	1 Hr. 8 Mins.	Clamshell bucket					Water
39.4							River bottom, -39.4'
39.8			1				Reddish sandy GRAVEL; Some indurated pieces; gravel rounded; some cobbles and occasional small boulder. (39.4-44.7)
44.7			2				Bottom of hole, -44.7'

112240 E
475400 N

NADP FORM 1104 (3-19)
1 SEP 60

TP437

BORING/TEST PIT LOG

PROJECT Del. R., Phila. to Sea	FIELD BOOK TP 20	PAGE — X
Sta 150+000 450' E ℄	BY Reardon	DATE 1/19/62

BORING [ ] TEST PIT [X]	NO. 436
LOCATION Sta. 150+000 450' E. ℄	
DATE MADE 1/19/62	BY Hired Labor
PLANT USED Derrickboat 37	

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	MATERIALS DESCRIPTION
0						Water
36.8	16 Minutes	Clamshell bucket				River bottom, -36.8'
39.0			1			Soft, darkgray organic SILT and CLAY with occasional fine sandy layers. (36.8 - 46.3)
46.3			2			Mat'l becomes stiffer @ 45.0' Bottom of hole, -46.3'

112500 E
~~479~~500 N

NADP FORM 1104 (3-19)
1 SEP 60

TP 436

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
[illegible]	[illegible]	2
Sta. 146 + 000 450 W ℄ [illegible]	BY [illegible]	DATE 1/22/62

Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery.	Graphic legend
1 Hr. 05 Mins.	clamshell bucket	1, 2			

☐ BORING ☒ TEST PIT NO. 438

LOCATION Sta. 146+000 450' W. ℄

DATE MADE 1/22/62 BY Hired Labor

PLANT USED Derrickboat 37

MATERIALS DESCRIPTION

Depth	Materials description
0	water
	River bottom, - 39.3'
39.3	Gray SAND & GRAVEL. (39.3 - 40.8)
40.8	Sandy GRAVEL with cobbles and small boulders; some reddish silt and clay. Small clay seam @ 42.6'. (40.8 - 45.0)
42.6	
45.0	Bottom of hole, - 45.0'

114[illegible] E
47-[illegible] N

NADP FORM 1104 (3-19)
1 SEP 60

TP438

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River	73	23
	BY P.G.L.	DATE 6-12-65

☐ BORING ☒ TEST PIT	NO. DRP-12
LOCATION 139+930 165' E of ¢	
DATE MADE 6-9-65	BY C of E
PLANT USED DB #37	

Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb.hammer w/ in.drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
						Water -41.2'
15		1				Sandy gravel w/ boulders 12"x2"x3" 48"x24"x24" and some cobbles. No fresh break noticed on boulders
						Bottom of TP - 43.3'

11576 = E
4?270 = N

NADP FORM 1104 (3-19)
1 SEP 60

DRP-12

BORING/TEST PIT LOG

PROJECT Delaware R., Ph. [illegible]	FIELD BOOK 34	PAGE 39
Sta. 119+420 On ℄	BY HARTZELL	DATE 9/6/61

☐ BORING ☒ TEST PIT	NO. 282
LOCATION Sta. 119+420 On ℄	
DATE MADE 9/6/61	BY E.P.H.
PLANT USED DB # 37	

136,150 E
493,870 N

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler, lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0 – 44.0	45 Minutes	Clamshell bucket					Water River bottom, - 44.0'
44.0 – 46.0			#1				Organic SILT; decayed vegetation; some gravelly layers. (44.0' - 50.0')
46.0 – 50.0			#2				
50.0							Bottom of TP, - 50.0'

✓

NADP FORM 1104 (3-19)
1 SEP 60

TP 282

BORING/TEST PIT LOG

PROJECT Delaware River - Phila to Sea	FIELD BOOK 73	PAGE 8	
Aquifer Studies	BY R.L	DATE 4-5-65	

☐ BORING	☒ TEST PIT	NO. DSR 16
LOCATION Sta: 76+210 500' W of ℄		
DATE MADE 4-1-65	BY CofE	
PLANT USED DB#34		

Water 46°F

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
							Water -47.8'
47							
	30 Minutes	3/4 cy clamshell bucket	1			SM	Brn & dk-gry silty SAND, some small gravel
50						OL	Dk-gry silty org CLAY, plastic, interbedded w/thin layers of fine sand
			2				
55							
60			3				same but more sandy layers
							Bottom of TP - 60.2'

NADP FORM 1104 (3-19)

DSR 16

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River - Phila to Sea	73	8
	BY R.L	DATE 4-5-65

BORING	TEST PIT (X)	NO. DSP-17
LOCATION Sta: 68+880 290' E of ℄		
DATE MADE 4-2-65	BY CofE	
PLANT USED DB#37		

Water 46°F

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
40							Water - 41.6'
45	45 Minutes	3/4 cy clamshell bucket	1			OL SM	Gry silty fine SAND, culm, and layers of org. clayey SILT (41.6'-48.0')
50			2			OL	Gry silty org. CLAY, fairly stiff, interbedded w/ lt. gry v. fine SAND (very thin layers) Ind. layers of clay ½" thick. (48.0'-51.4
55			3			SP	Sand, fine to coarse, tr of gravel (51.4 - 59.0')
60			4			ML Pt	Brn sandy SILT w/some peat & rotten wood, soft

NADP FORM 1101 (2-19)

DSP17

BORING/TEST PIT LOG

PROJECT Delaware River - Phila to Sea	FIELD BOOK 73	PAGE 9
Aquifer Studies	BY R.L.	DATE 4-5-65

BORING ☒ TEST PIT — NO. DSP19

LOCATION Sta: 50+230 310' W of ℄

DATE MADE 4-2-65 — BY CofE

PLANT USED DB#37

Water 46°F

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery	Graphic legend	MATERIALS DESCRIPTION
45							Water -47.8'
	30 Minutes		1			OL	Gry org. silty CLAY, plastic, thinly interbedded w/ gry fine sand. Fairly firm (47.8'-49.3')
50			2				
						GP	Gravel, sandy up to 1½" subangular to subrounded, loose (49.3'-54.0')
55			3			SP	Sand fine to v. coarse w/ some pea gravel
							Bottom of TP - 54.8'

517821 N
1978205 E

NADP FORM 1104 (3-19)

DSP19

BORING/TEST PIT LOG

PROJECT	FIELD BOOK	PAGE
Delaware River Phila to Sea Aquifer Studies.	73	10
	BY R.L	DATE 4-6-65

BORING [ ] TEST PIT [X] NO. DSP20

LOCATION Sta 41+890 290' E of ℄

Water 46°F

DATE MADE 4-3-65 BY C of E

PLANT USED Derrickboat #37

Depth	Drilling/Excavating Time	Type penetration	Sample No.	Blows/ft. on sampler - lb. hammer w/ in. drop	Core barrel run no. and percent core recovery.	Graphic legend	MATERIALS DESCRIPTION
0 – 40							Water -43.5
43.5 – 51.6	60 Minutes	3/4 cy clamshell bucket	1			OL & SM	Very thin veneer of brn f-med SAND underlain by interbedded gr. clayey org. SILT & v. fine silty SAND. (layers same thickness) (43.5- 51.6)
51.6 – 60.1			2, 3			SM	Silty v. fine SAND, compact, interbedded w/ some dk-gry org. SILT (Predominantly silty SAND) (51.6'- 60.1')
60.1							Bottom of TP - 60.1'

517500N
256+00 E

NADP FORM 1104 (3-10)

DSP20

Appendix B
Delaware Main Channel Acoustic Core Density Plots

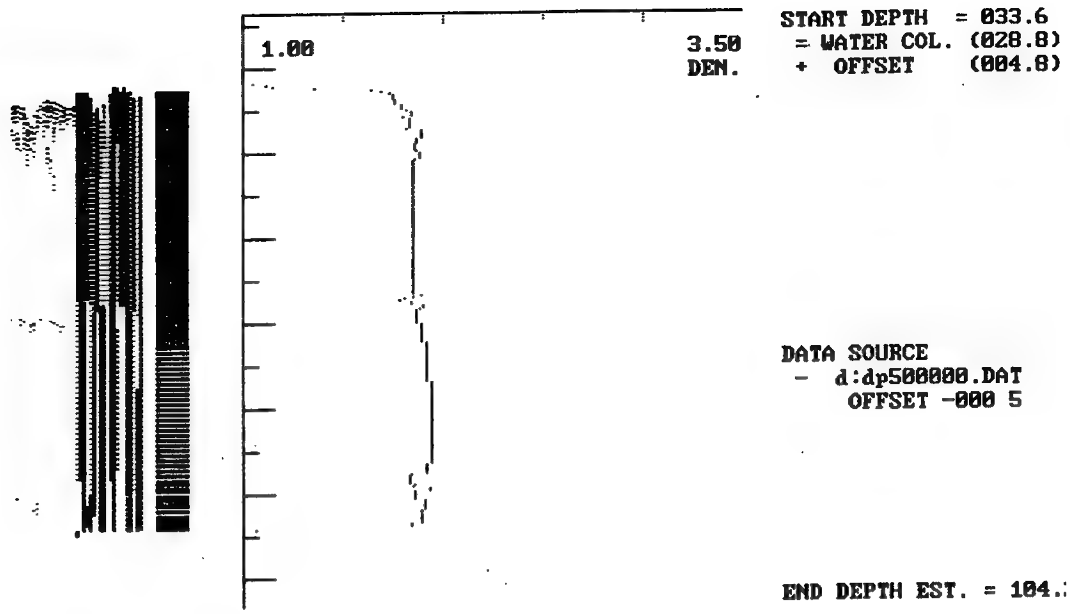
This appendix presents density versus depth plots for selected acoustic data files. These plots are referenced on the sediment profile plots (Plates 2-15) with the prefix AC followed by the line number and individual file number. These "Acoustic Core" density plots are presented in ascending order along each survey profile.

A typical density plot in this appendix consists of three normally color-coded vertical profile columns as shown on the left of each figure. The plots are presented in black and white to conserve printing costs, negating the benefits of color-coding the results and therefore making the amplitude and impedance versus depth portions of the plots difficult to distinguish. The first column is the acoustic amplitude segment for the data subfile, consisting of 40 consecutive soundings. The second column is coded impedance segment calculations while the third column depicts an average of the previous impedance calculations. The final calculation, density as a function of depth, is then plotted. It is important to note that the S/N degrades with depth causing erroneous impedance calculations. This is indicated on the plot by a black color code on the impedance segment that is probably indistinguishable on the black and white copies provided here. For the plots presented, the bottom 5-10 ft of the density profile is basically unusable information due to the S/N.

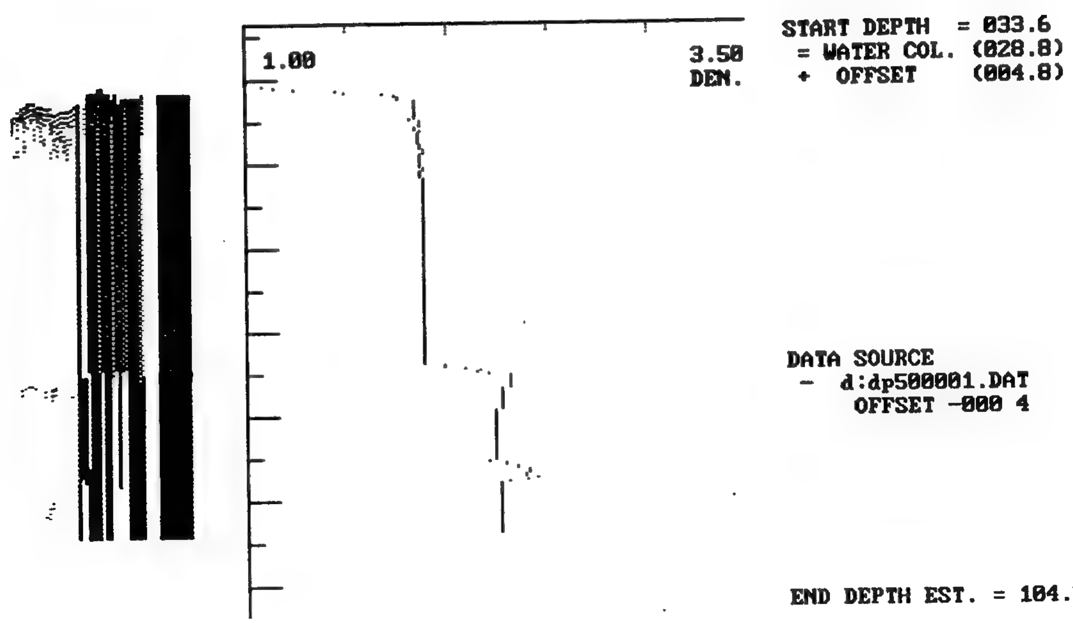
Table B1 cross-references the plots in this appendix with the plates in the main text.

Table B1
Acoustic Core Density Plots

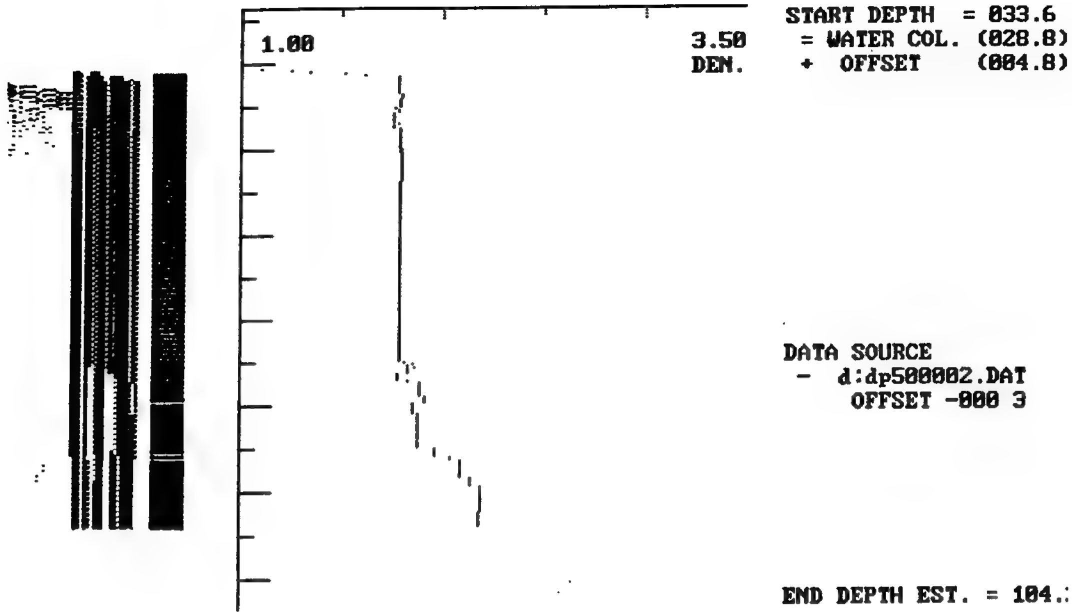
Survey Line	Plate in Main Text
DP50	2
DP51	3
DP52	4
SC04A	5
SC04B	6
SC04C	7
SC05	8
SC06A	9
SC06B	10
SC06C	11
SC06D	12
SC06E	13
SC06F	14
SC06G	15
SC96H	16
SC06H	16

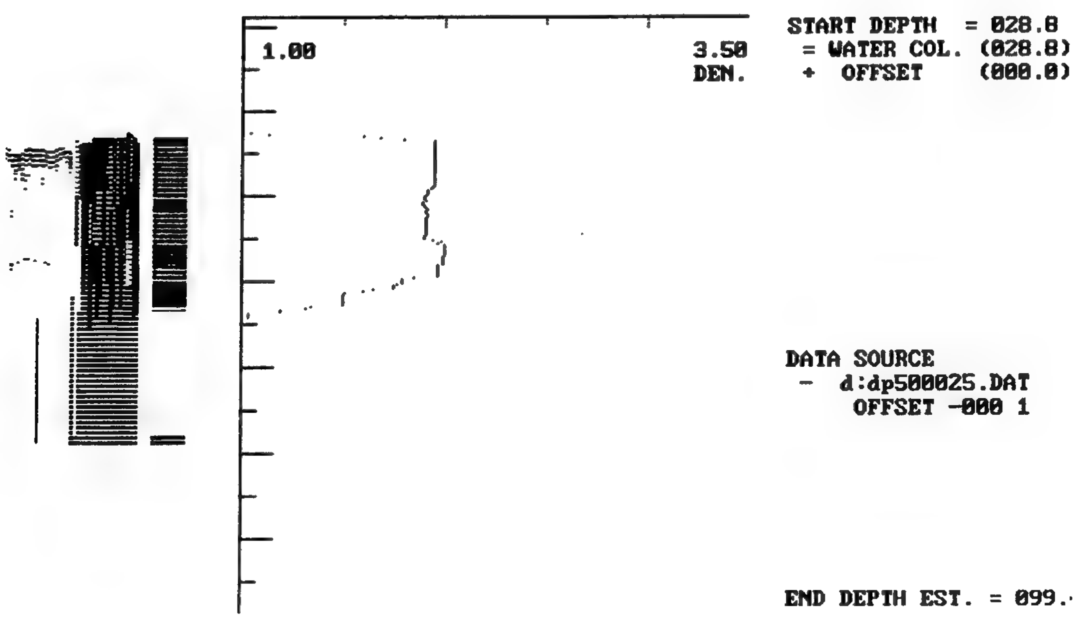


1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500000.DAT
OFFSET -000 5
END DEPTH EST. = 104.



1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500001.DAT
OFFSET -000 4
END DEPTH EST. = 104.


1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500002.DAT
OFFSET -000 3
END DEPTH EST. = 104.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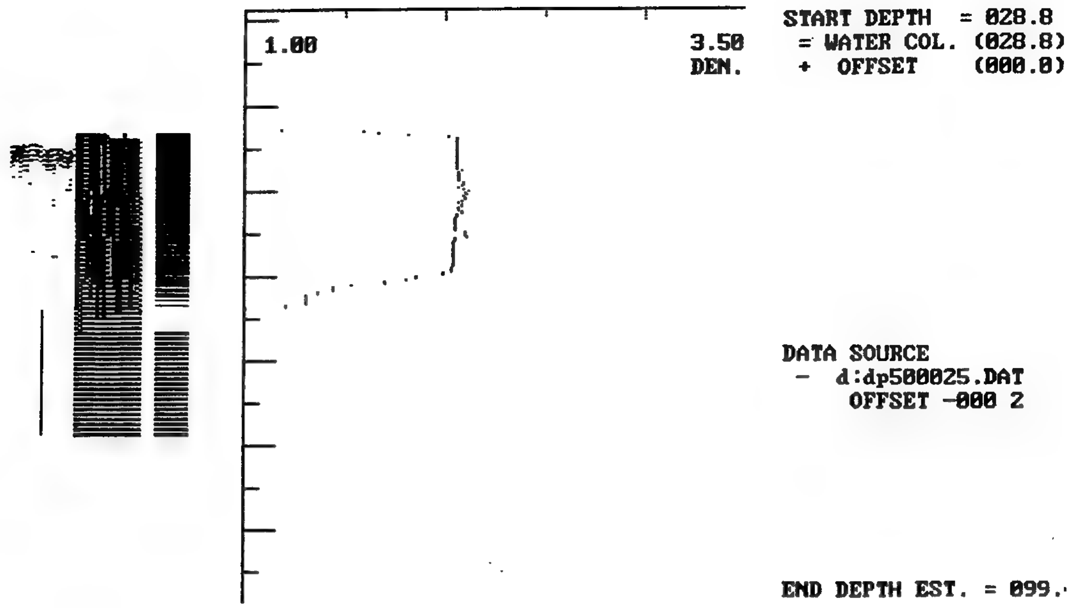
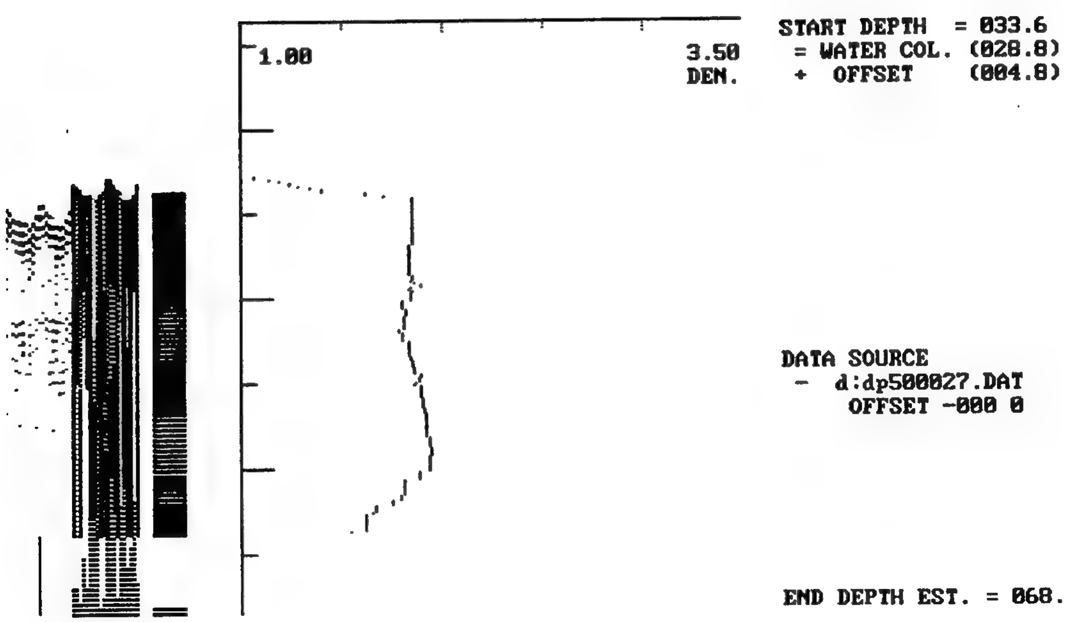
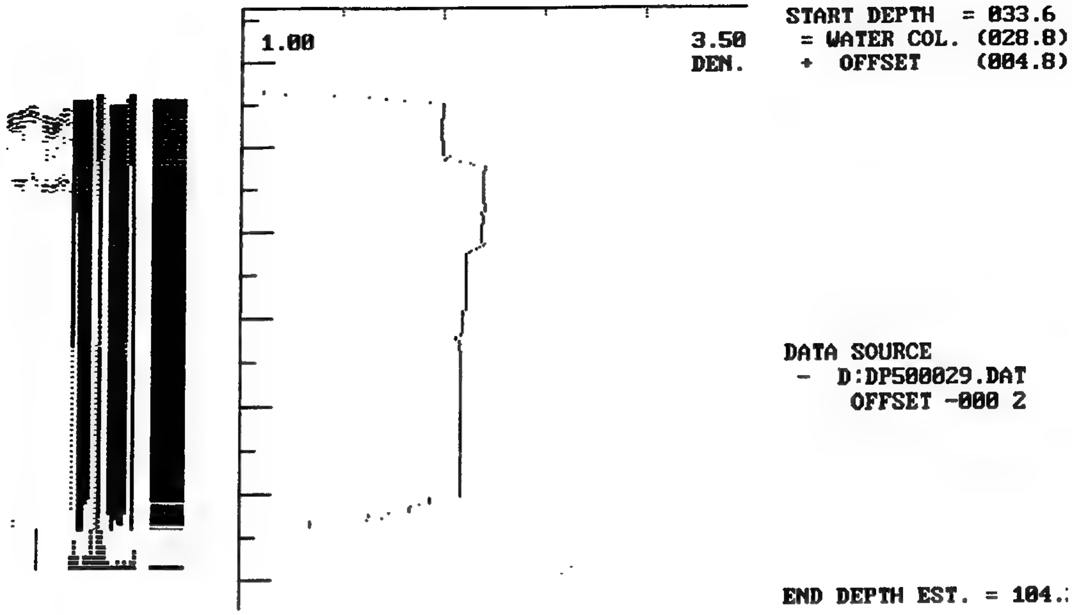
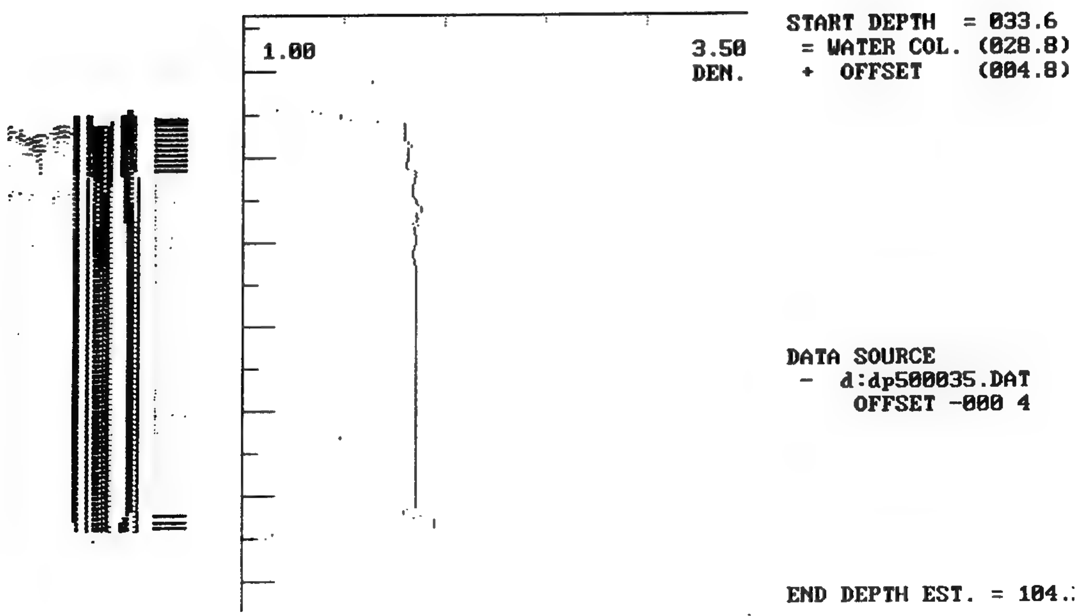
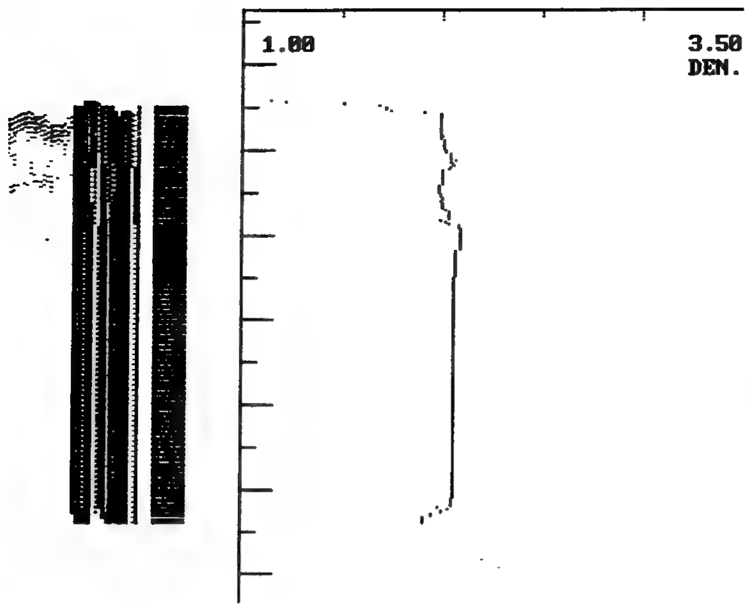
3.50
DEN.
START DEPTH = 028.8
= WATER COL. (028.8)
+ OFFSET (000.0)
DATA SOURCE
- d:dp500025.DAT
OFFSET -000 1
END DEPTH EST. = 099.


1.00
3.50
DEN.
START DEPTH = 028.8
= WATER COL. (028.8)
+ OFFSET (000.0)
DATA SOURCE
- d:dp500025.DAT
OFFSET -000 2
END DEPTH EST. = 099.


1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500027.DAT
OFFSET -000 0
END DEPTH EST. = 068.'


1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500029.DAT
OFFSET -000 2
END DEPTH EST. = 104.

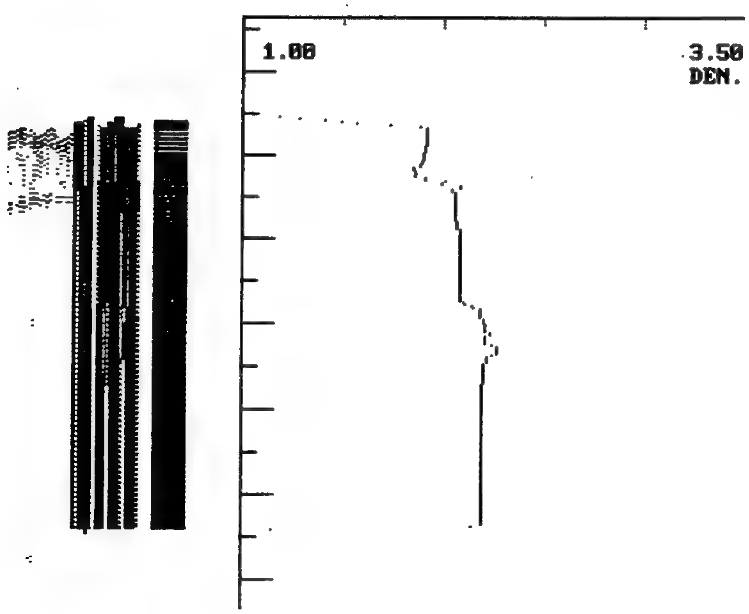

1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500035.DAT
OFFSET -000 4
END DEPTH EST. = 104.



START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)

DATA SOURCE
– d:dp500035.DAT
OFFSET -000 5

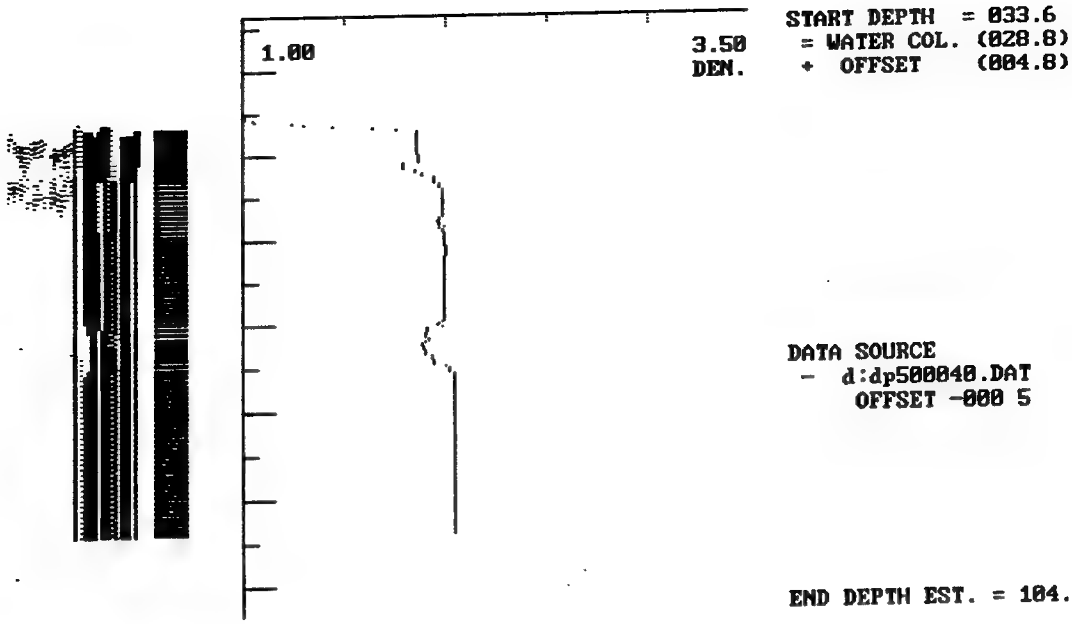
END DEPTH EST. = 104.:

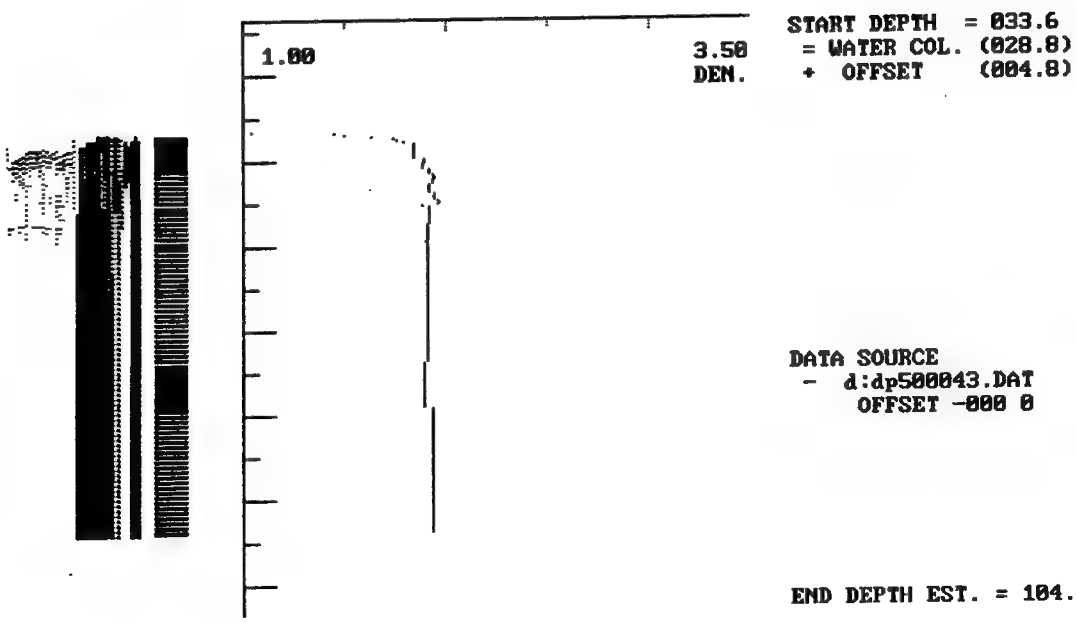


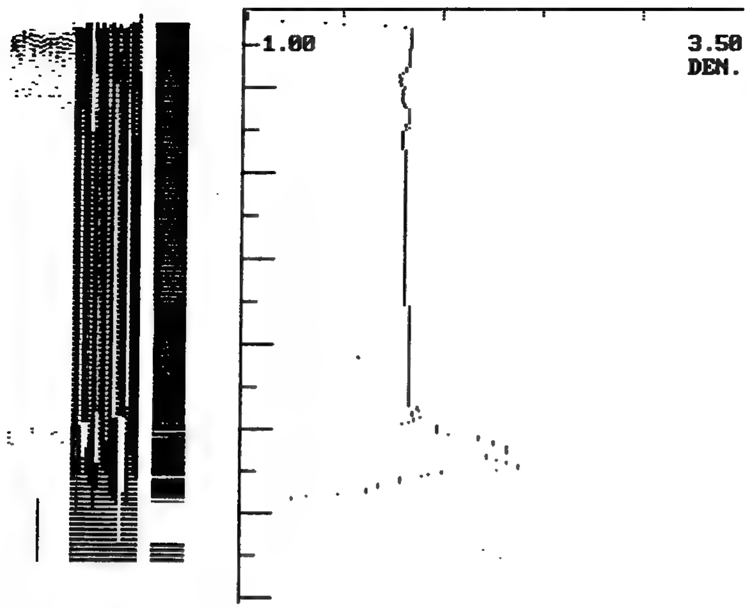
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)

DATA SOURCE
– d:dp500040.DAT
OFFSET -000 0

END DEPTH EST. = 104.:


1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500040.DAT
OFFSET -000 5
END DEPTH EST. = 104.:

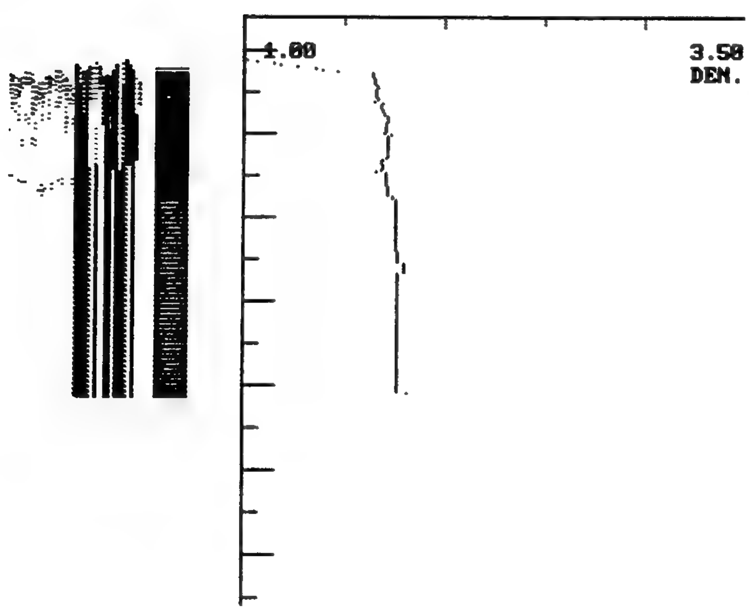

1.00
3.50
DEN.
START DEPTH = 033.6
= WATER COL. (028.8)
+ OFFSET (004.8)
DATA SOURCE
- d:dp500043.DAT
OFFSET -000 0
END DEPTH EST. = 104.:



START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP500055.DAT
OFFSET -000 0

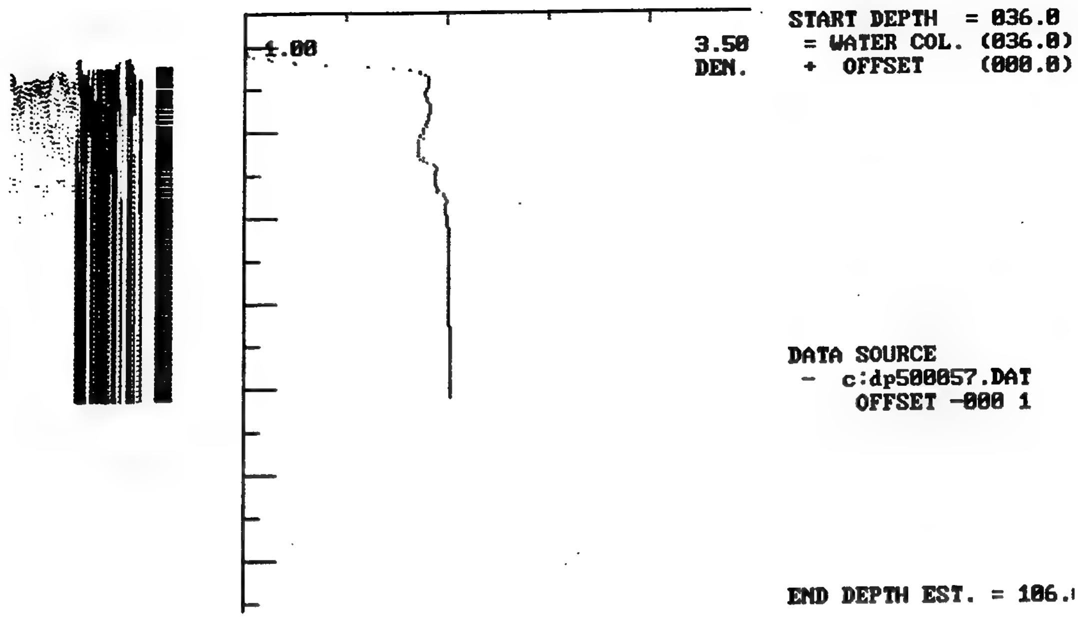
END DEPTH EST. = 111.

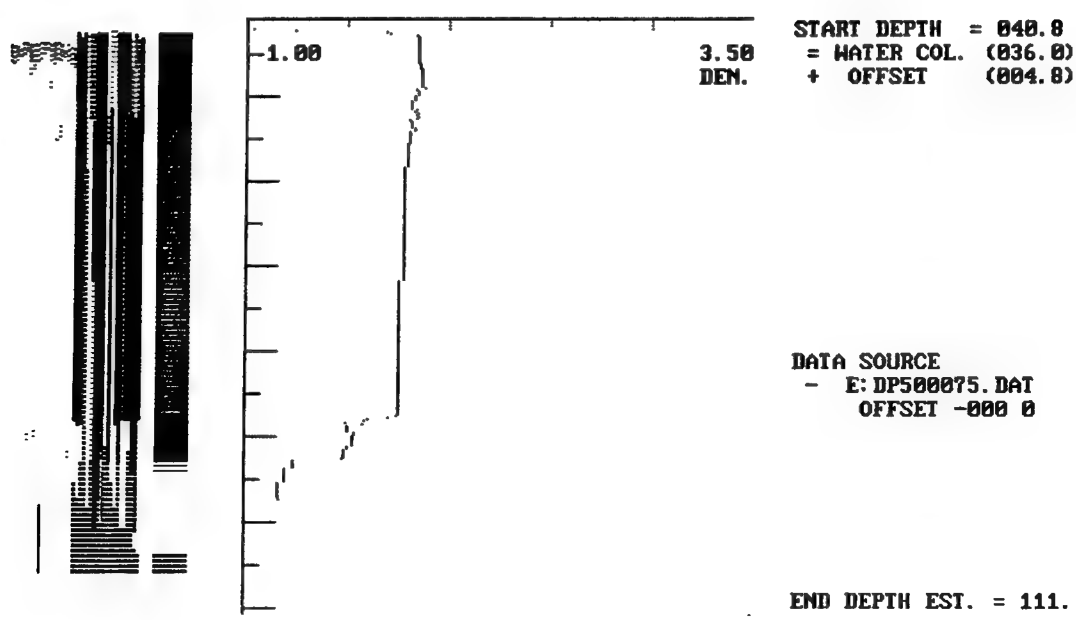


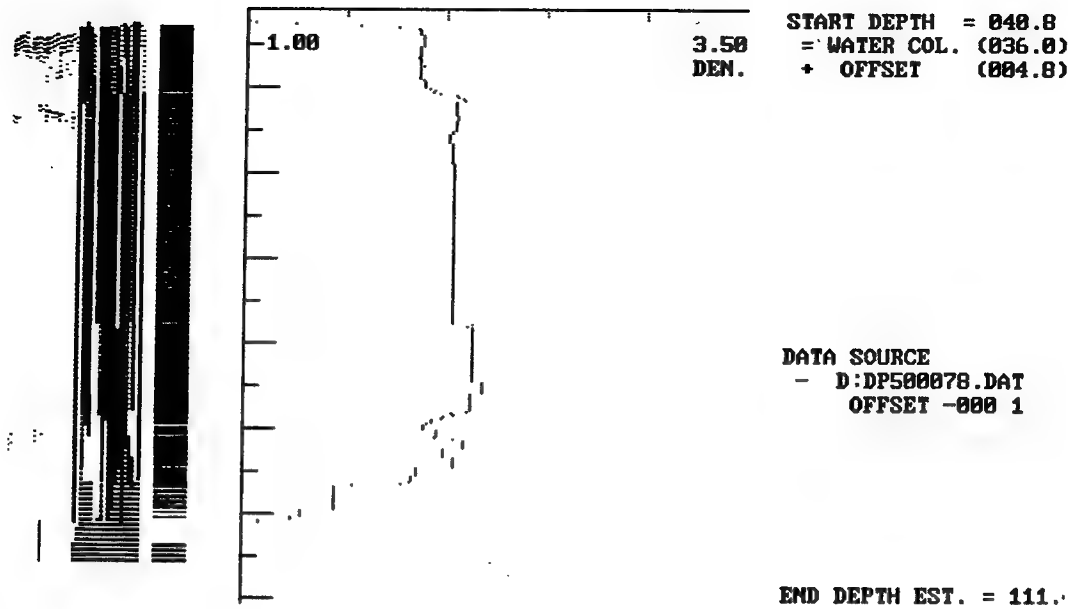
START DEPTH = 036.0
= WATER COL. (036.0)
+ OFFSET (000.0)

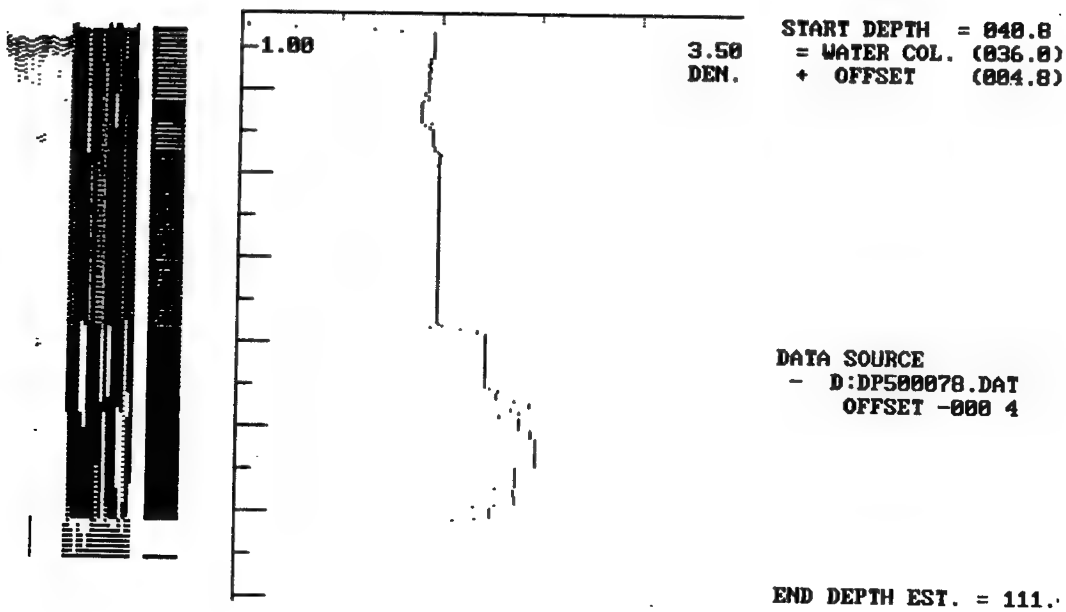
DATA SOURCE
- c:dp500056.DAT
OFFSET -000 4

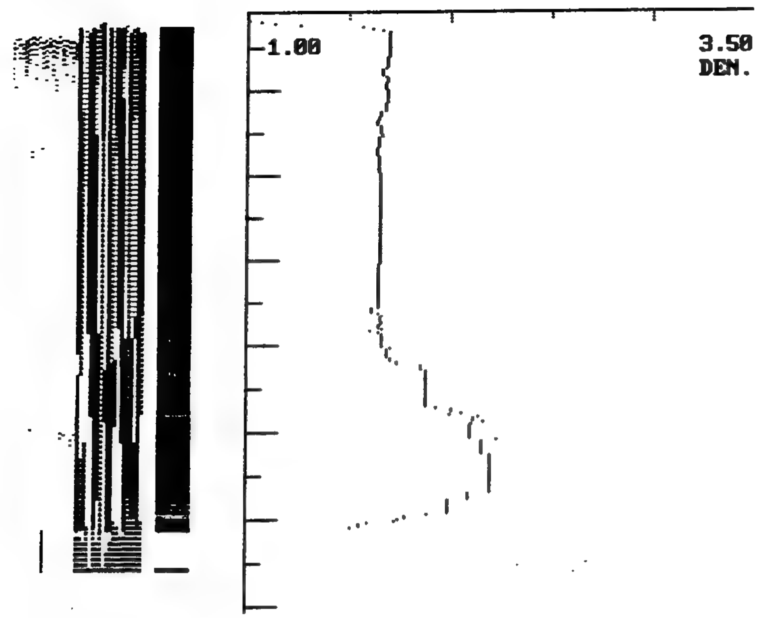
END DEPTH EST. = 106.


-1.00
3.50
DEN.
START DEPTH = 036.0
= WATER COL. (036.0)
+ OFFSET (000.0)
DATA SOURCE
- c:dp500057.DAT
OFFSET -000 1
END DEPTH EST. = 106.


-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- E: DP500075. DAT
OFFSET -000 0
END DEPTH EST. = 111.


-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500078.DAT
OFFSET -000 1
END DEPTH EST. = 111.

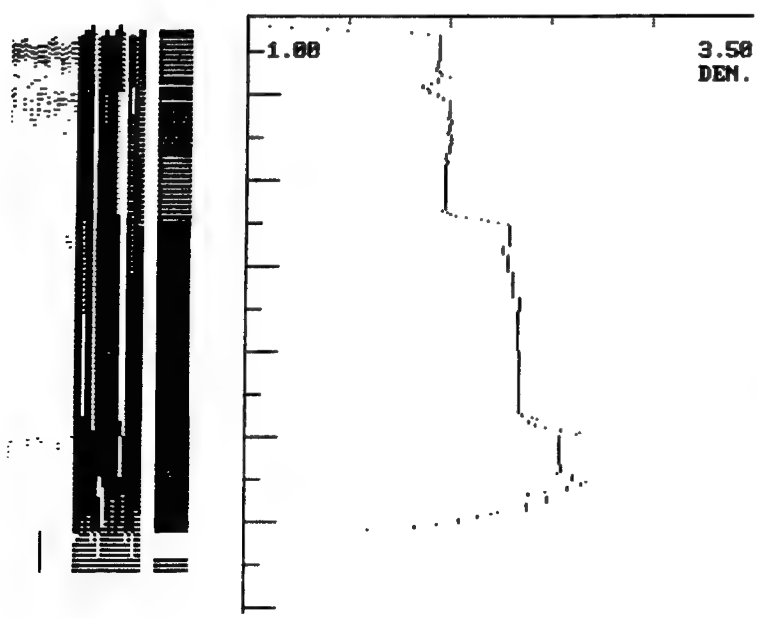

-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500078.DAT
OFFSET -000 4
END DEPTH EST. = 111.



START DEPTH = 040.0
= WATER COL. (036.0)
+ OFFSET (004.0)

DATA SOURCE
- D:DP500082.DAT
OFFSET -000 4

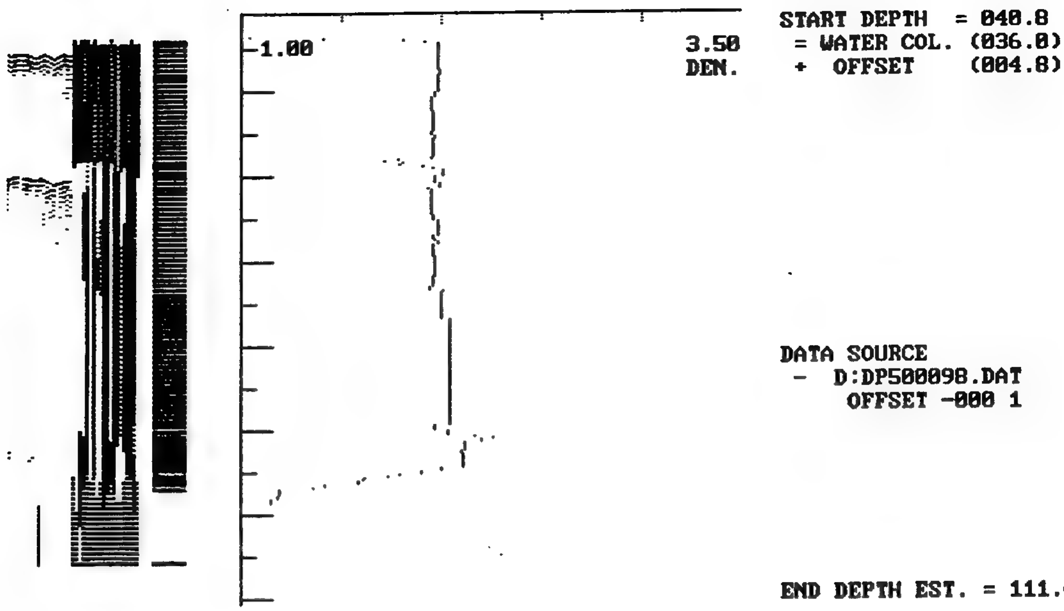
END DEPTH EST. = 111.

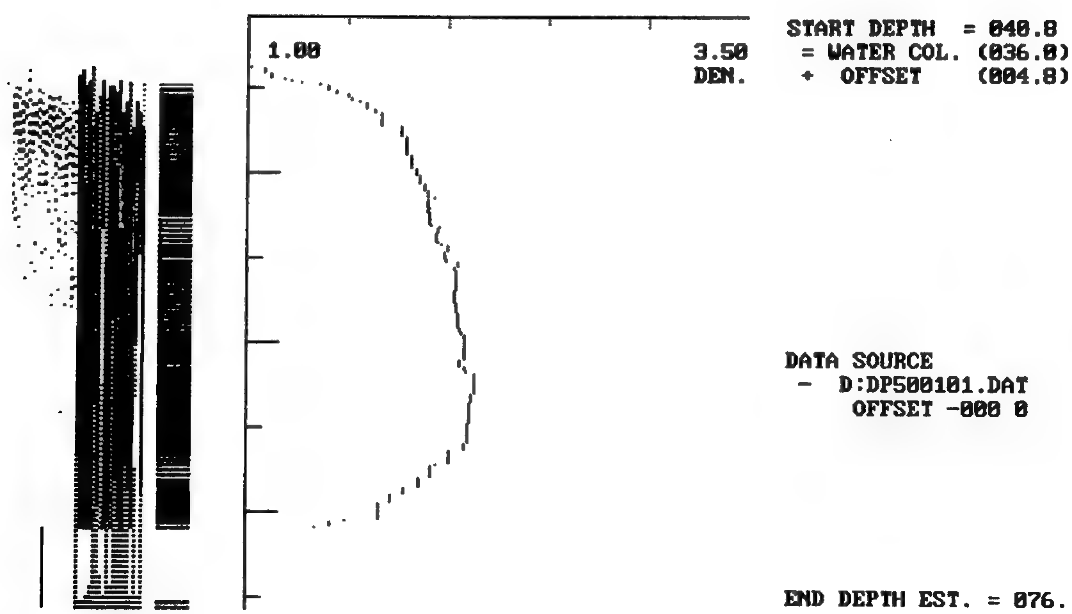


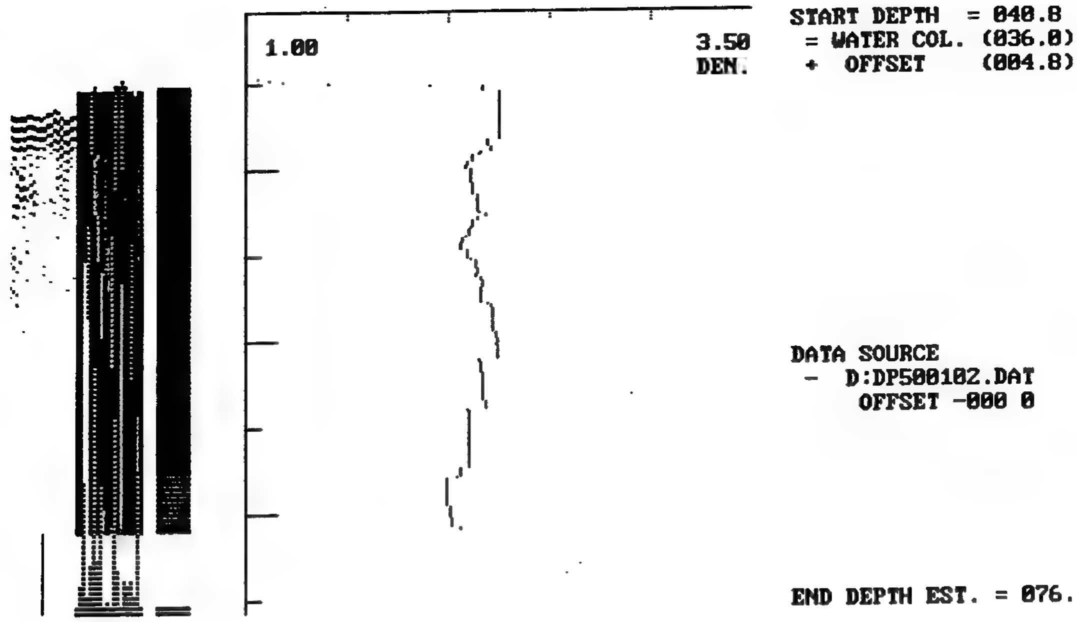
START DEPTH = 040.0
= WATER COL. (036.0)
+ OFFSET (004.0)

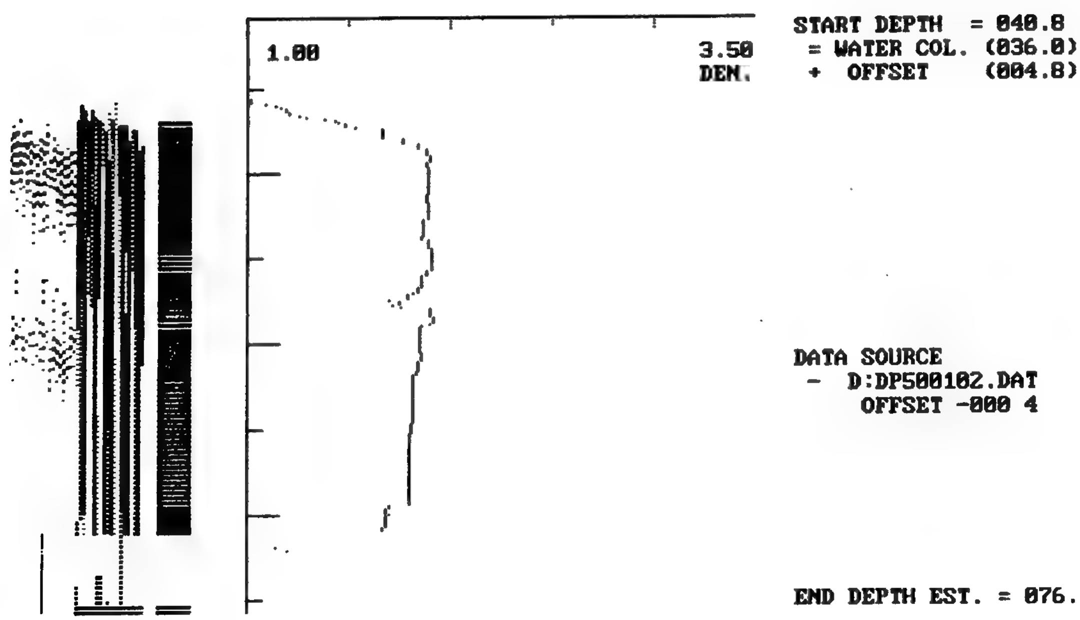
DATA SOURCE
- D:DP500094.DAT
OFFSET -000 1

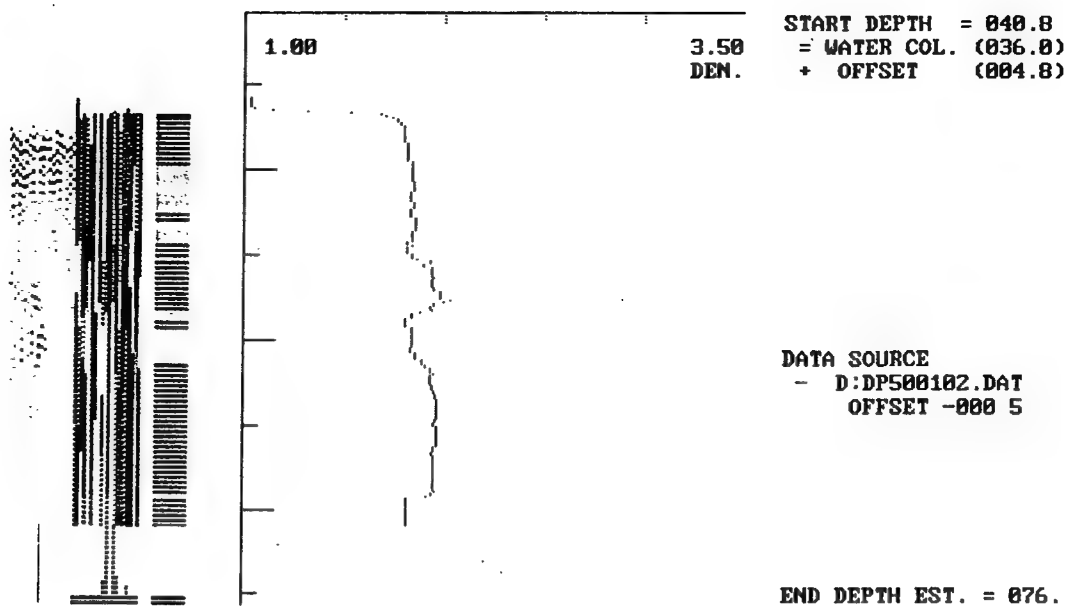
END DEPTH EST. = 111.

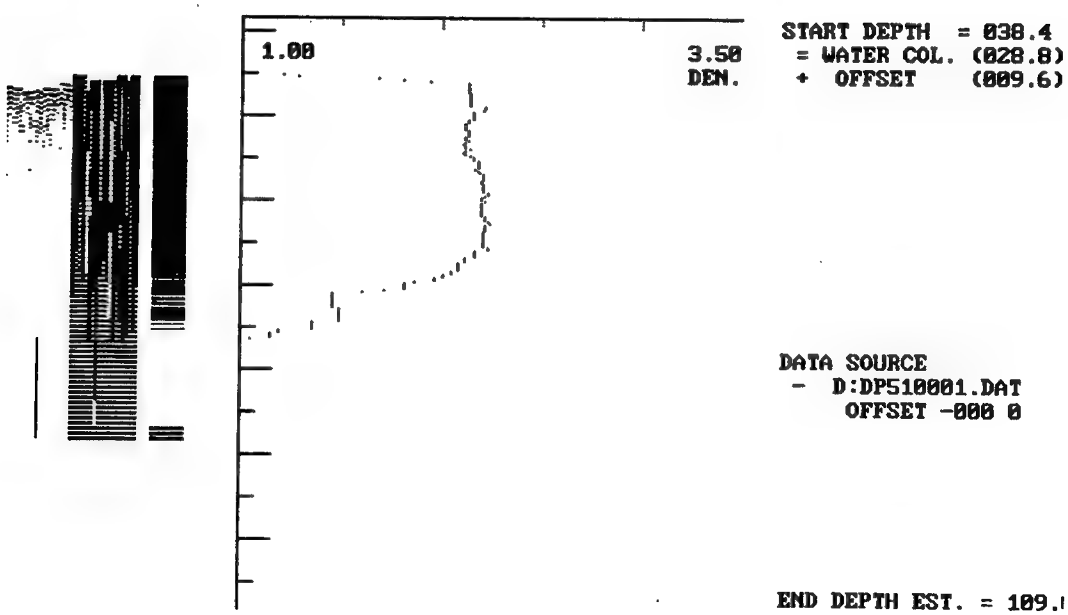

1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500098.DAT
OFFSET -000 1
END DEPTH EST. = 111.

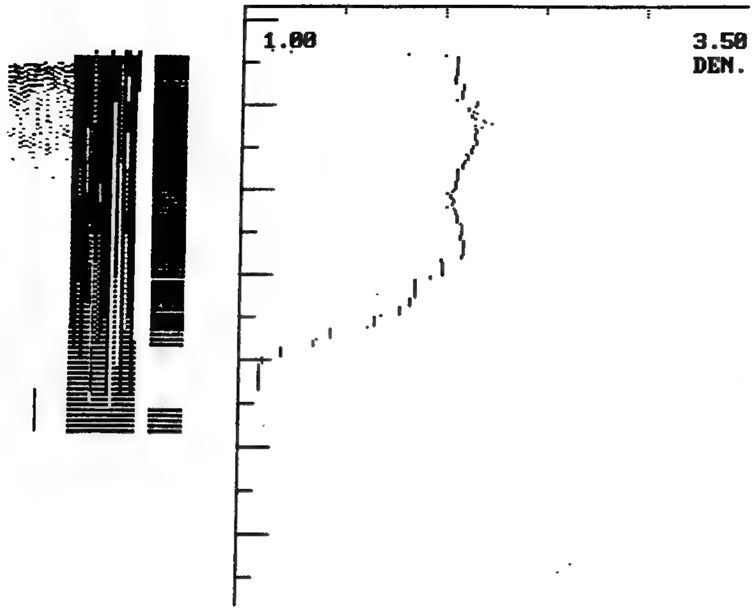

1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500101.DAT
OFFSET -000 0
END DEPTH EST. = 076.


1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500102.DAT
OFFSET -000 0
END DEPTH EST. = 076.


1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500102.DAT
OFFSET -000 4
END DEPTH EST. = 076.


1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP500102.DAT
OFFSET -000 5
END DEPTH EST. = 076.

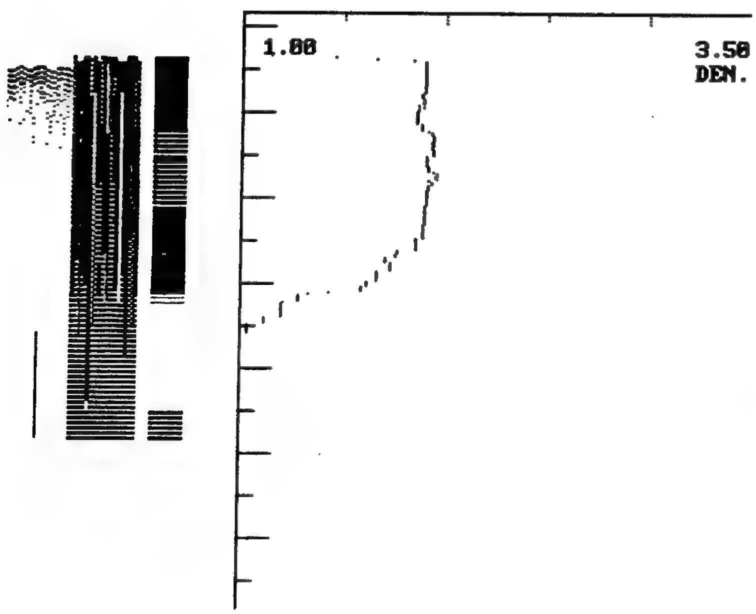

1.00
3.50
DEN.
START DEPTH = 038.4
= WATER COL. (028.8)
+ OFFSET (009.6)
DATA SOURCE
- D:DP510001.DAT
OFFSET -000 0
END DEPTH EST. = 109.



START DEPTH = 038.4
= WATER COL. (028.8)
+ OFFSET (009.6)

DATA SOURCE
- D:DP510002.DAT
OFFSET -000 0

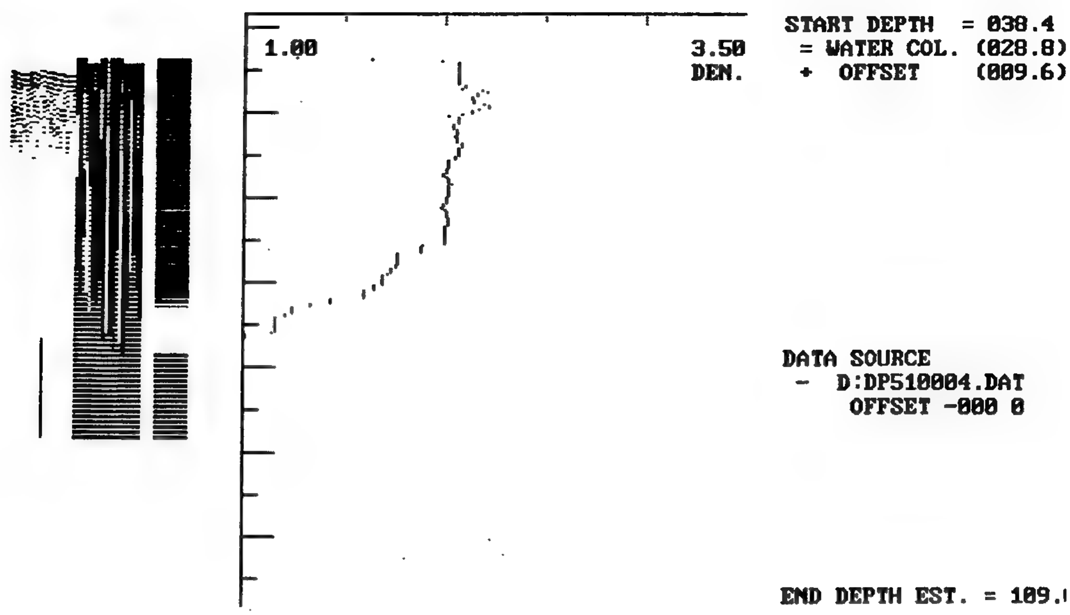
END DEPTH EST. = 109.1



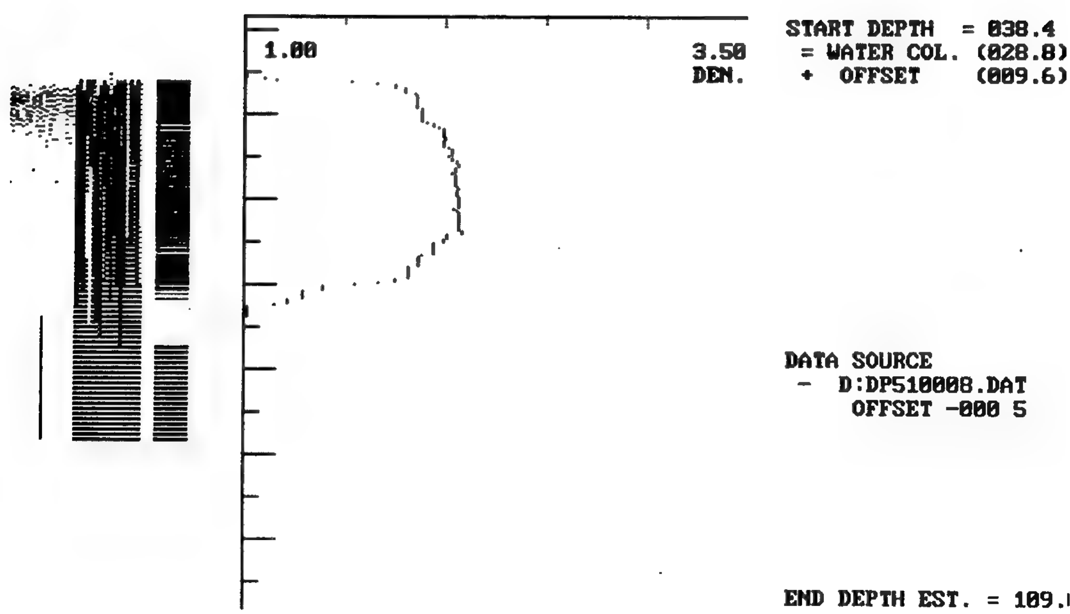
START DEPTH = 038.4
= WATER COL. (028.8)
+ OFFSET (009.6)

DATA SOURCE
- D:DP510003.DAT
OFFSET -000 0

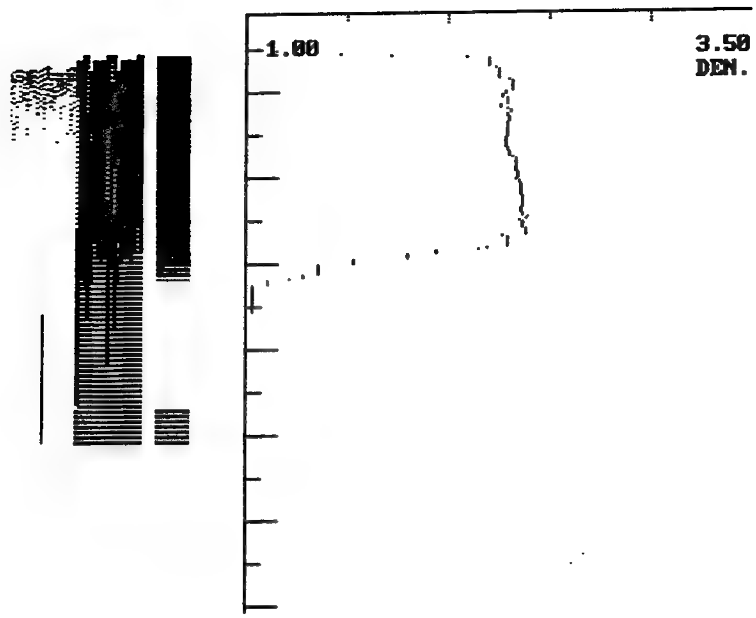
END DEPTH EST. = 109.1



1.00
3.50
DEN.
START DEPTH = 038.4
= WATER COL. (028.8)
+ OFFSET (009.6)
DATA SOURCE
- D:DP510004.DAT
OFFSET -000 0
END DEPTH EST. = 109.1



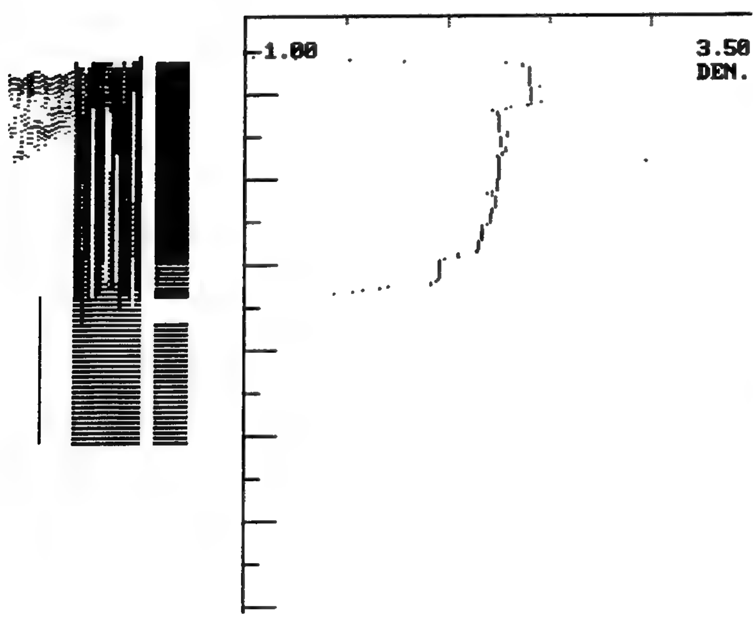
1.00
3.50
DEN.
START DEPTH = 038.4
= WATER COL. (028.8)
+ OFFSET (009.6)
DATA SOURCE
- D:DP510008.DAT
OFFSET -000 5
END DEPTH EST. = 109.1



START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP510012.DAT
OFFSET -000 0

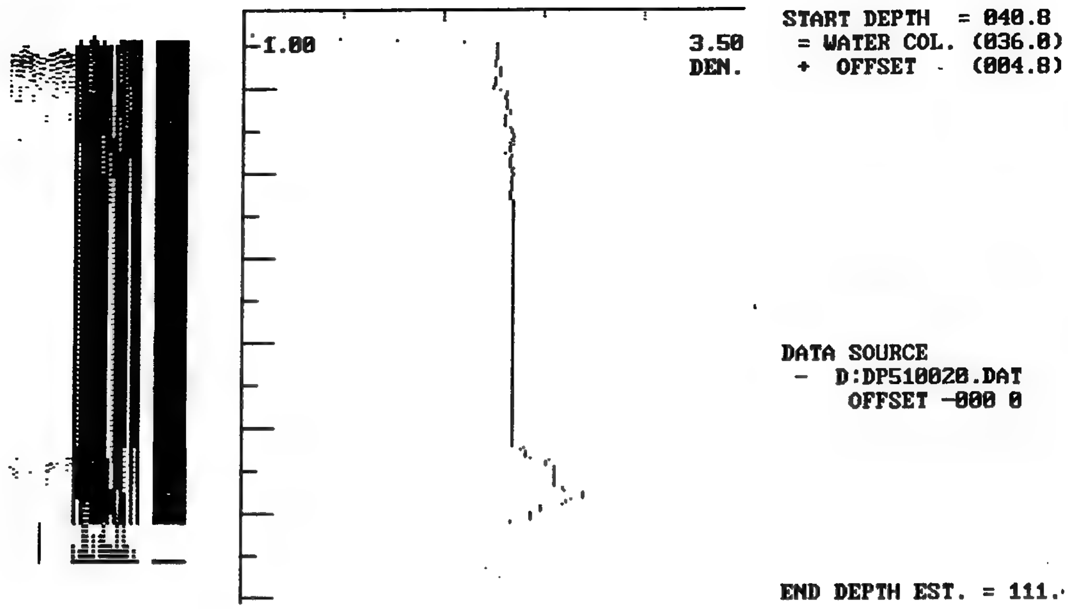
END DEPTH EST. = 111.

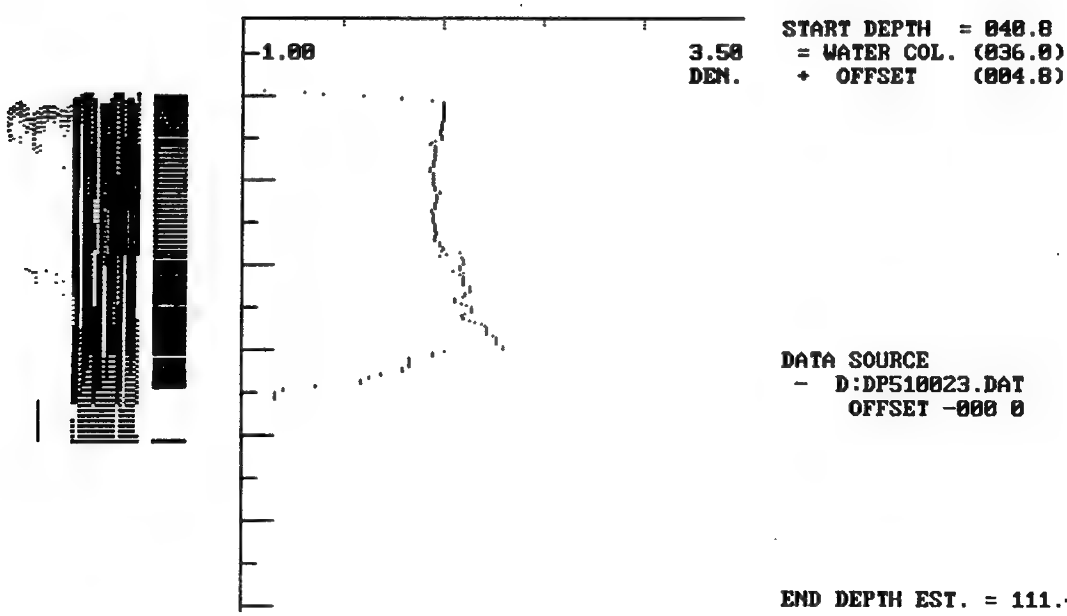


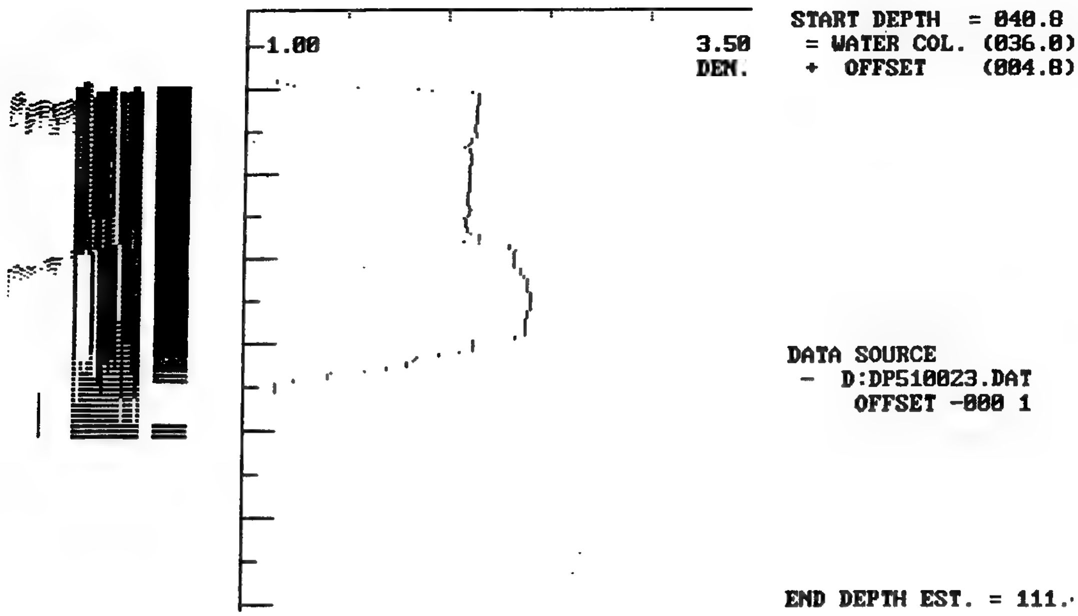
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

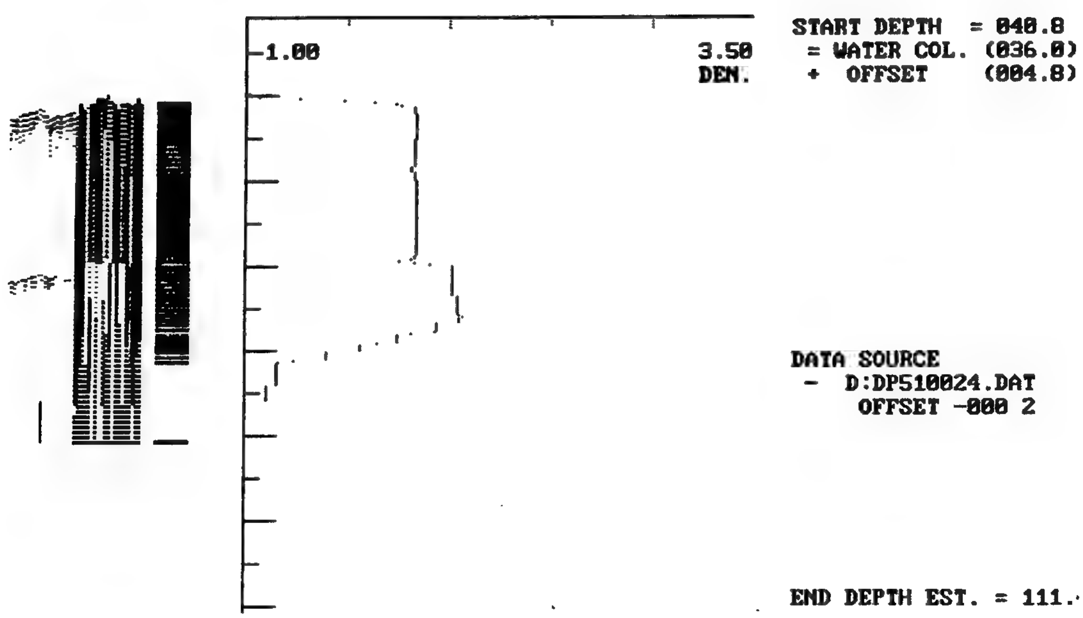
DATA SOURCE
- D:DP510016.DAT
OFFSET -000 5

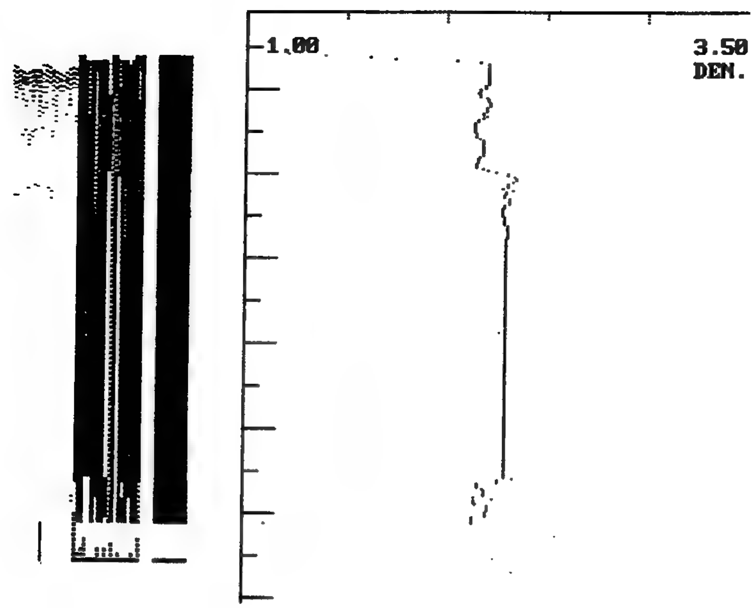
END DEPTH EST. = 111.


-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510020.DAT
OFFSET -000 0
END DEPTH EST. = 111.


-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510023.DAT
OFFSET -000 0
END DEPTH EST. = 111.


-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510023.DAT
OFFSET -000 1
END DEPTH EST. = 111.

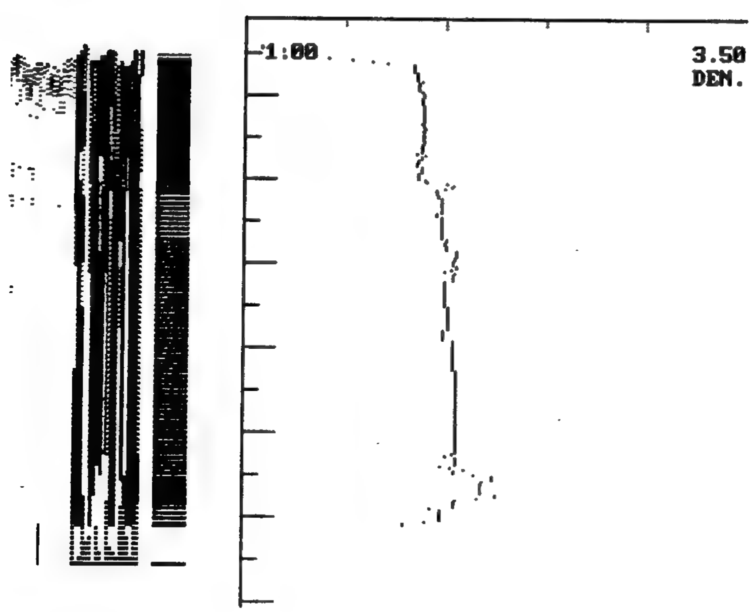

-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510024.DAT
OFFSET -000 2
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP510028.DAT
OFFSET -000 0

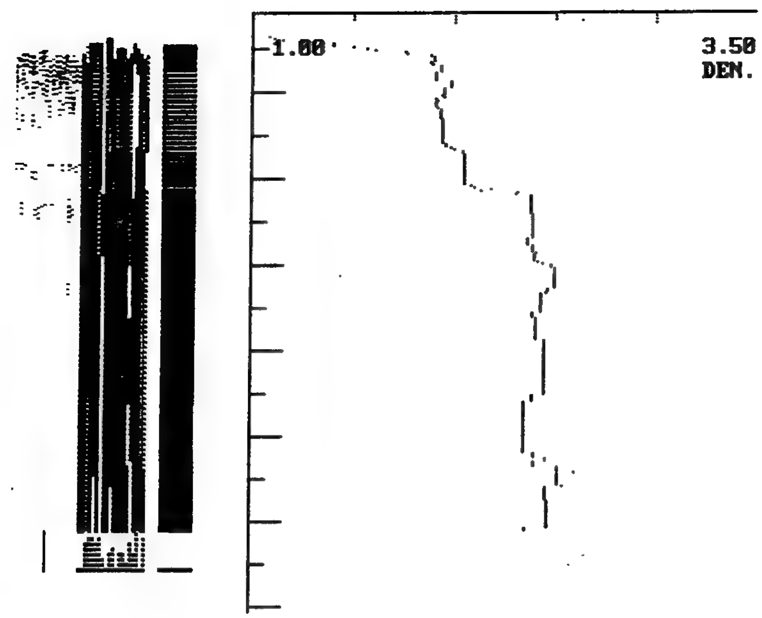
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP510030.DAT
OFFSET -000 0

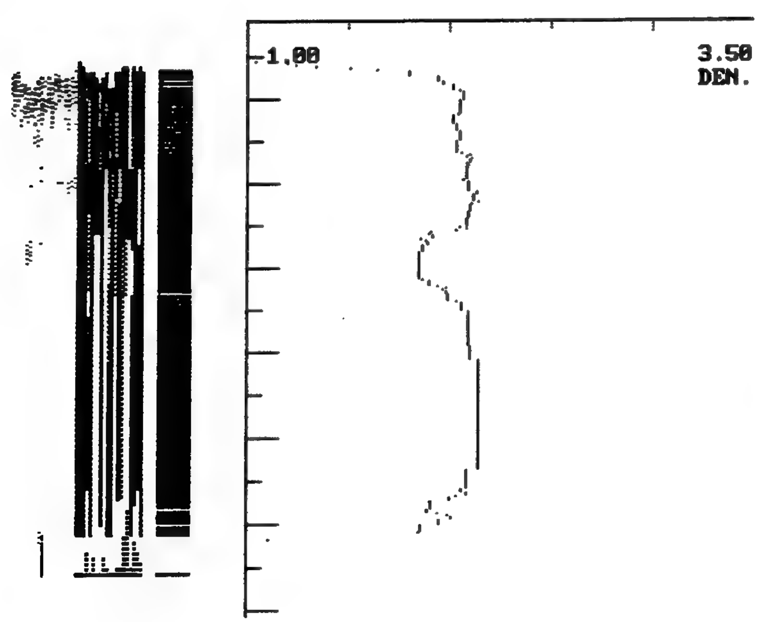
END DEPTH EST. = 111.



START DEPTH = 040.0
= WATER COL. (036.0)
+ OFFSET (004.0)

DATA SOURCE
- D:DP510030.DAT
OFFSET -000 4

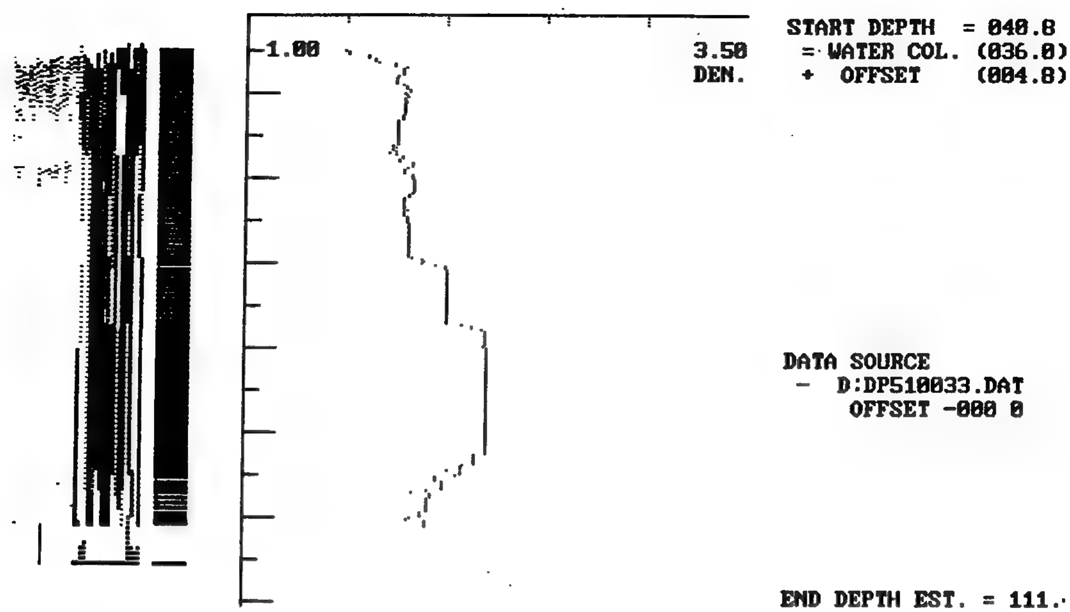
END DEPTH EST. = 111.

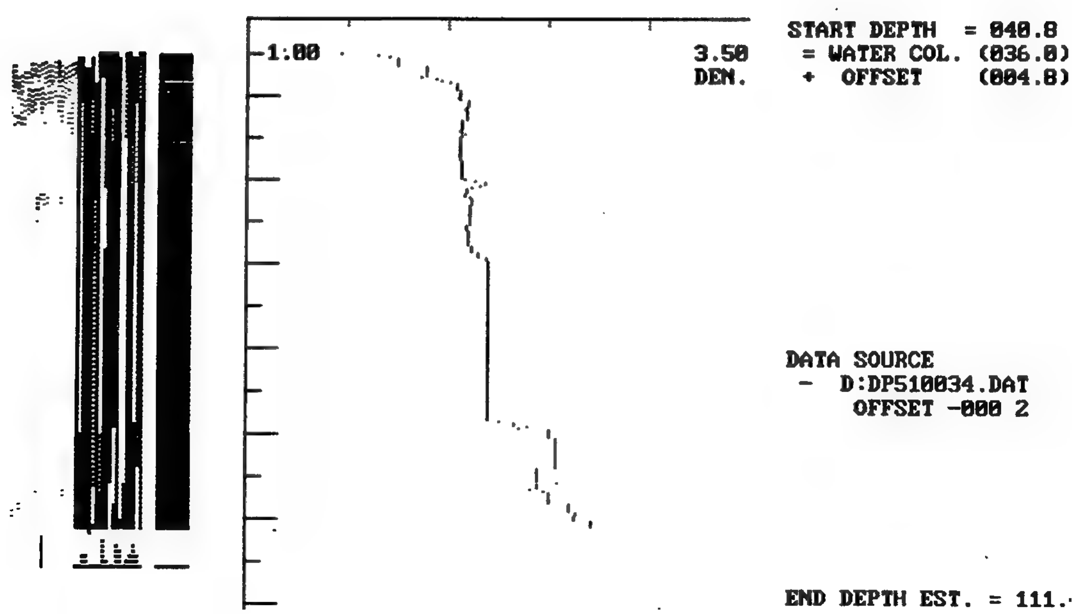


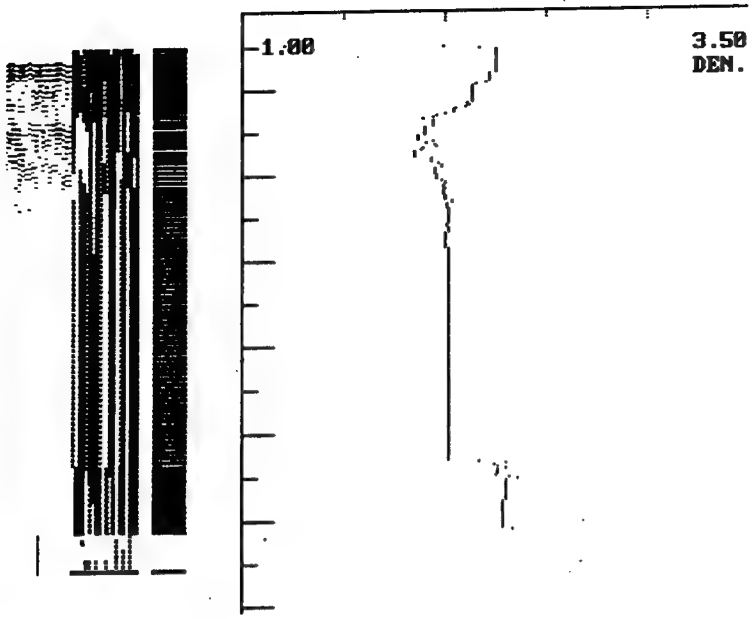
START DEPTH = 040.0
= WATER COL. (036.0)
+ OFFSET (004.0)

DATA SOURCE
- D:DP510032.DAT
OFFSET -000 0

END DEPTH EST. = 111.


1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510033.DAT
OFFSET -000 0
END DEPTH EST. = 111.

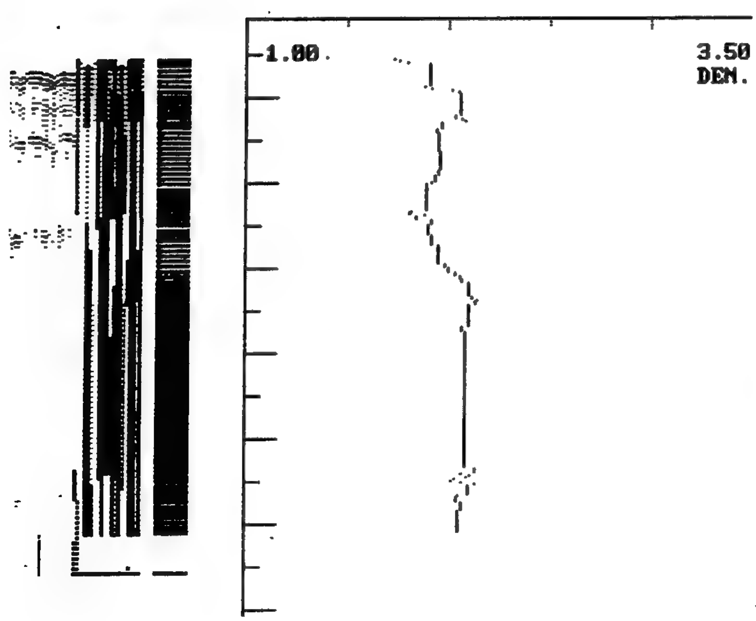

1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510034.DAT
OFFSET -000 2
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP510037.DAT
OFFSET -000 0

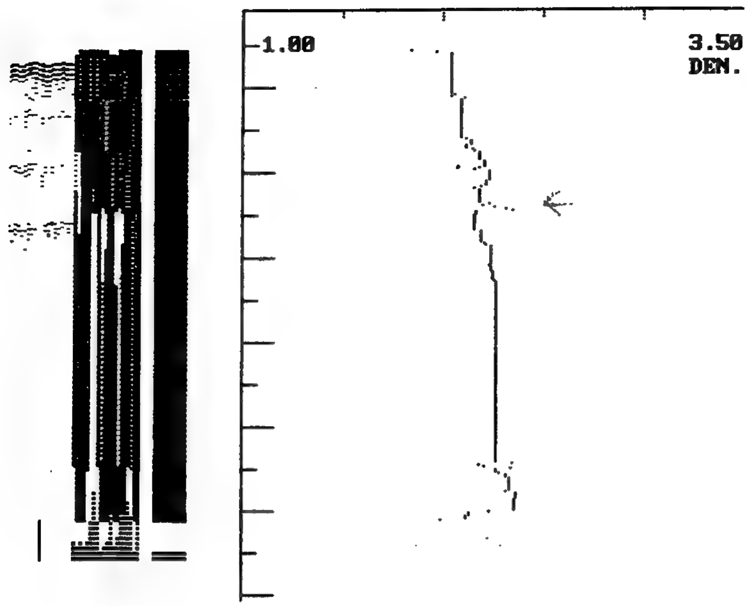
END DEPTH EST. = 111.



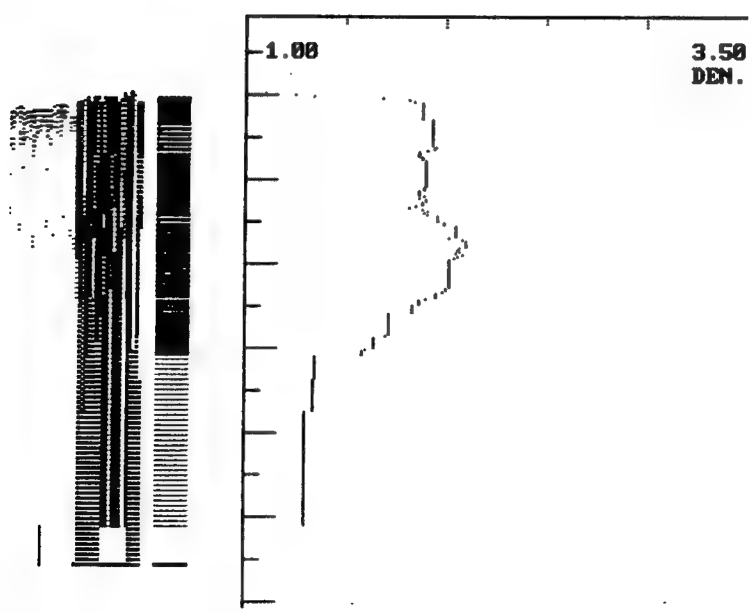
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)

DATA SOURCE
- D:DP510040.DAT
OFFSET -000 2

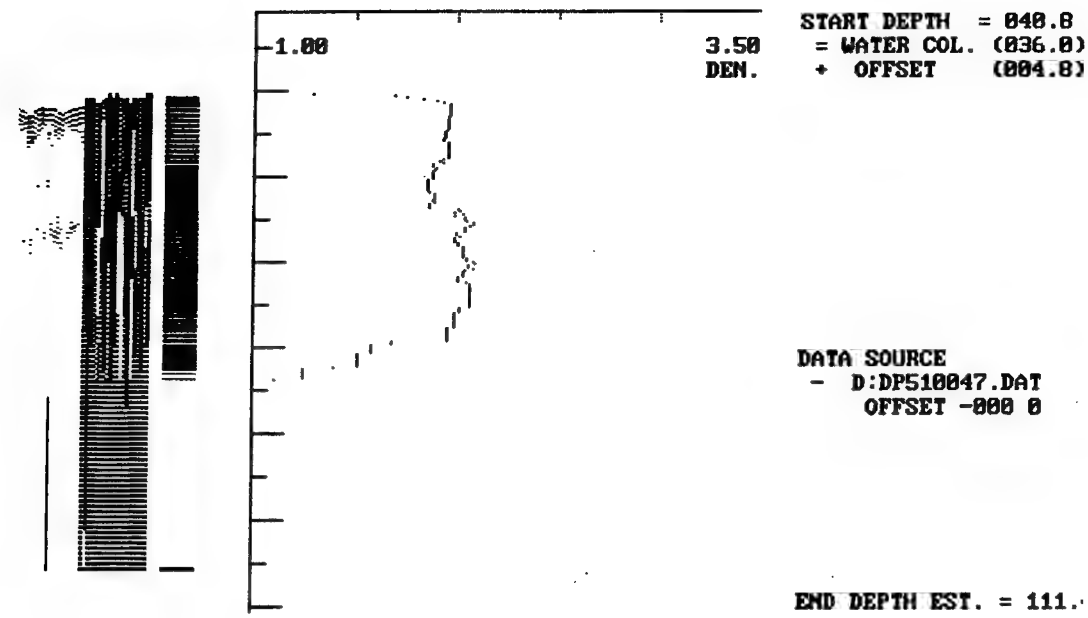
END DEPTH EST. = 111.



1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510042.DAT
OFFSET -000 3
END DEPTH EST. = 111.



1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510044.DAT
OFFSET -000 4
END DEPTH EST. = 111.



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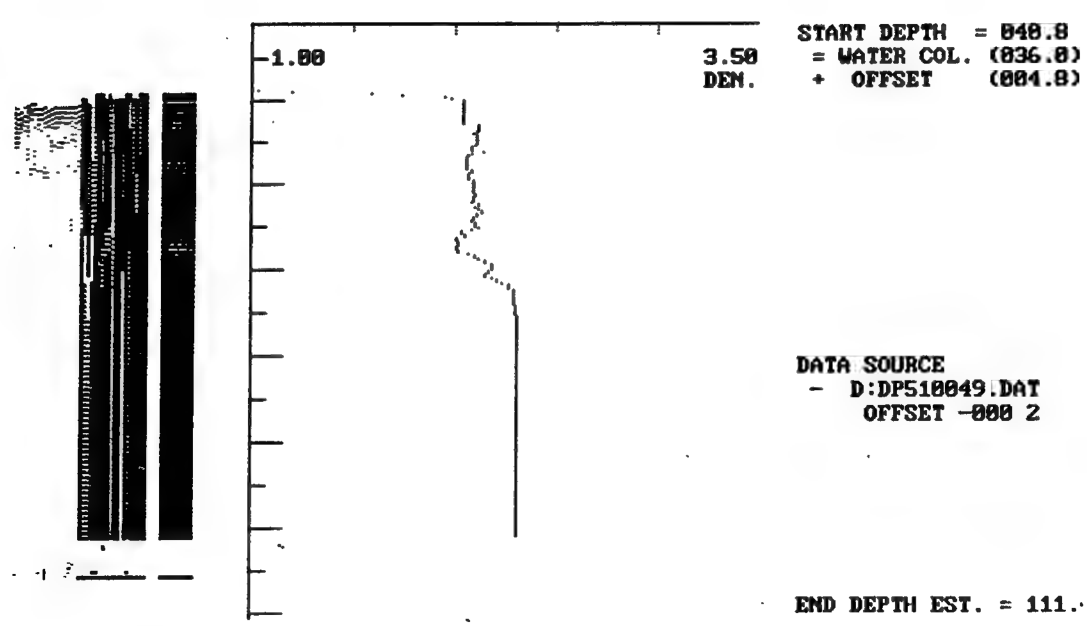
DEN.
START DEPTH = 040.8
= WATER COL. (036.0)
+ OFFSET (004.8)
DATA SOURCE
- D:DP510047.DAT
OFFSET -000 0
END DEPTH EST. = 111.



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DEN.
START DEPTH = 040.8
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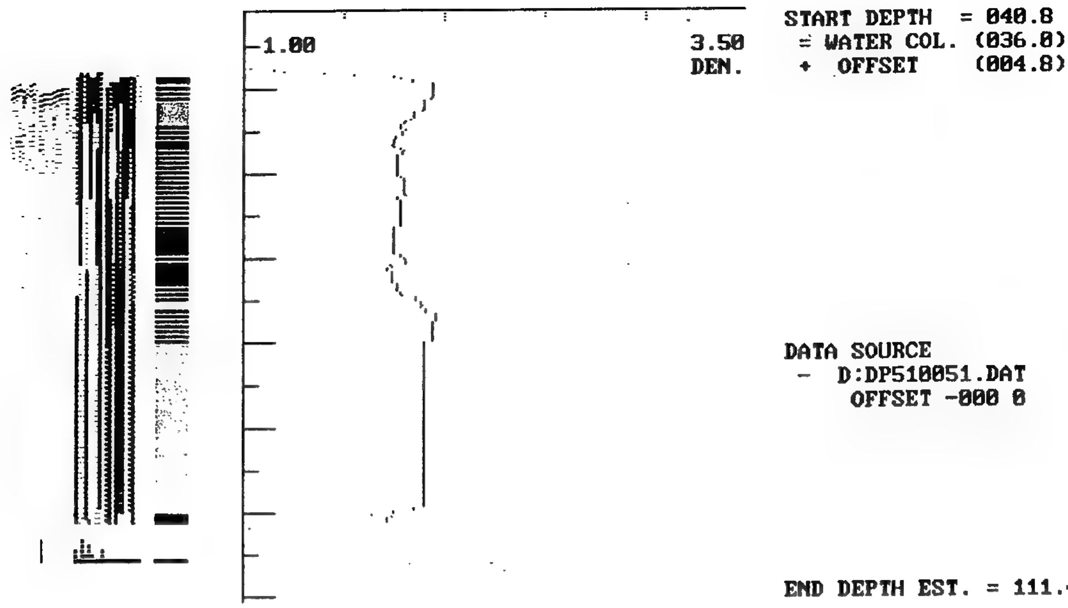
+ OFFSET (004.8)
DATA SOURCE
- D:DP510049.DAT
OFFSET -000 2
END DEPTH EST. = 111.



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START DEPTH = 040.8
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+ OFFSET (004.8)
DATA SOURCE
- D:DP510051.DAT
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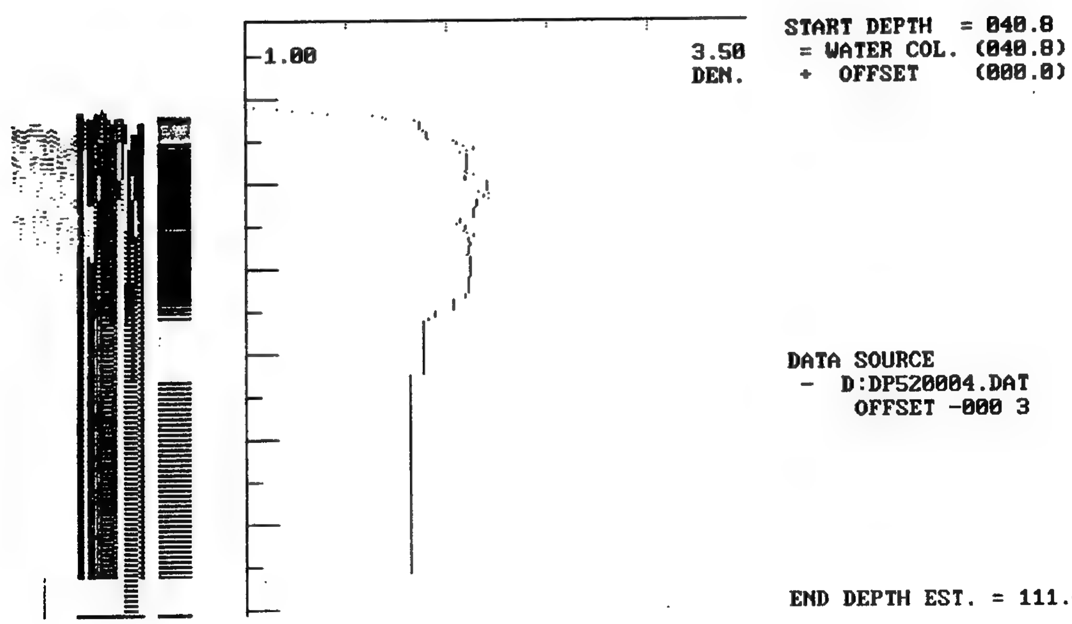

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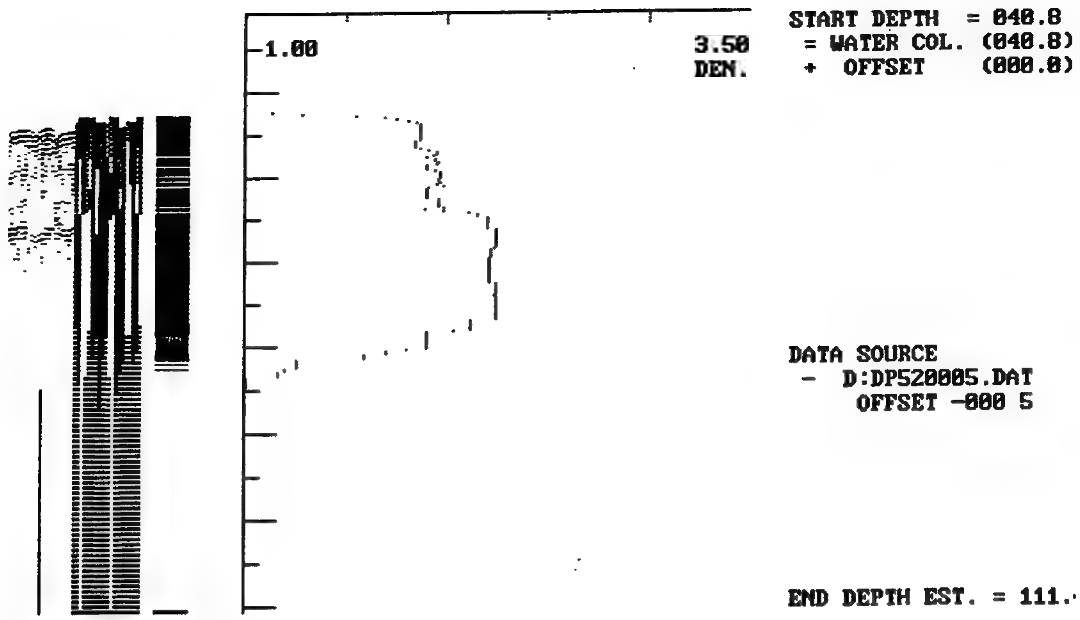
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520004.DAT
OFFSET -000 3
END DEPTH EST. = 111.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START DEPTH = 040.8
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+ OFFSET (000.0)
DATA SOURCE
- D:DP520005.DAT
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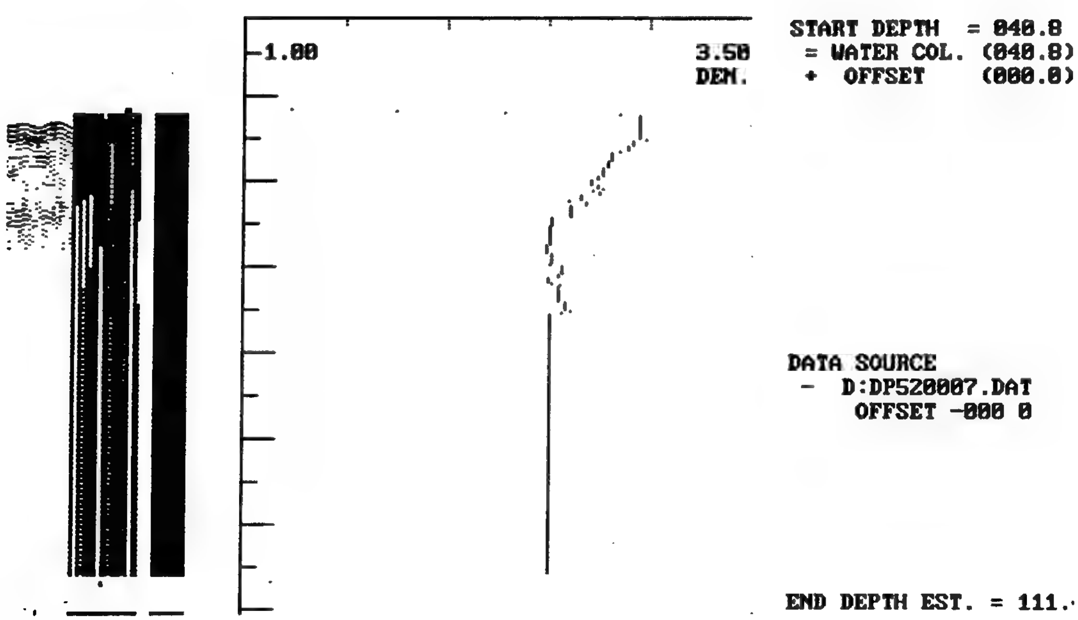
END DEPTH EST. = 111.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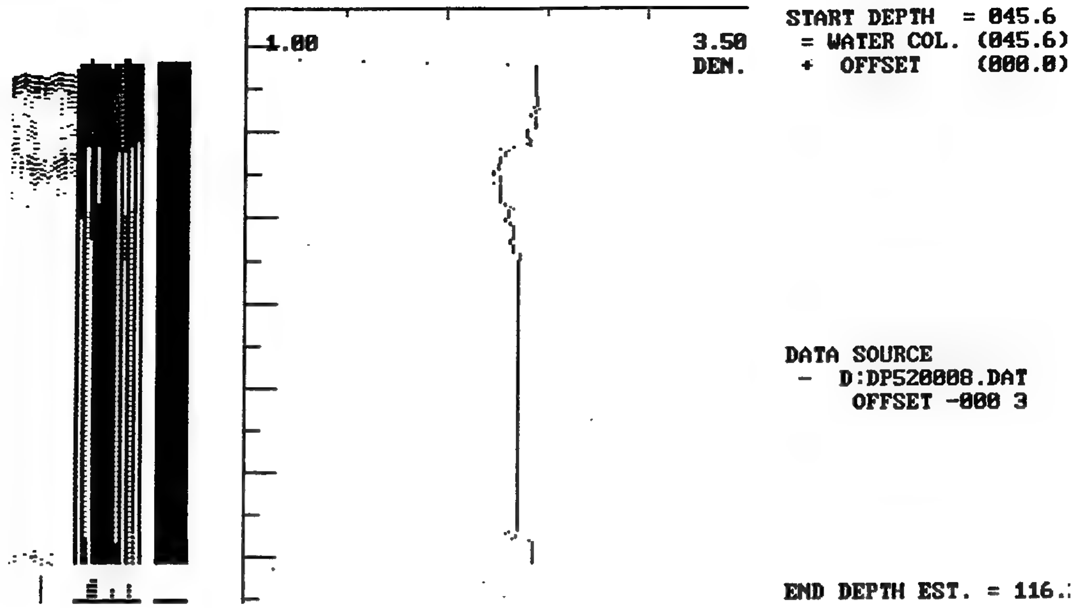
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520007.DAT
OFFSET -000 0
END DEPTH EST. = 111.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START DEPTH = 045.6
= WATER COL. (045.6)
+ OFFSET (000.0)
DATA SOURCE
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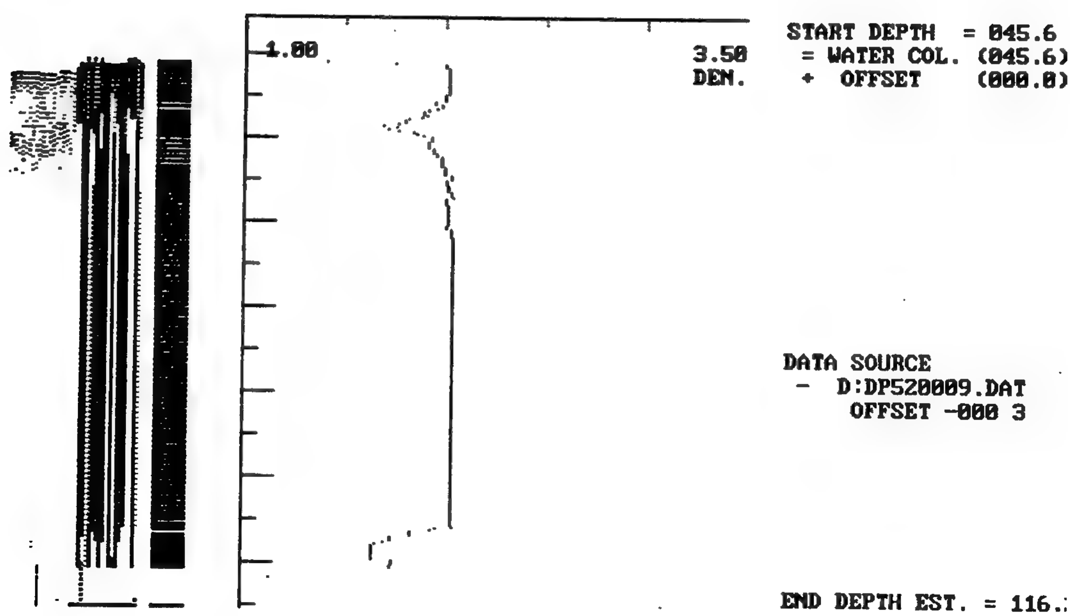
OFFSET -000 3
END DEPTH EST. = 116.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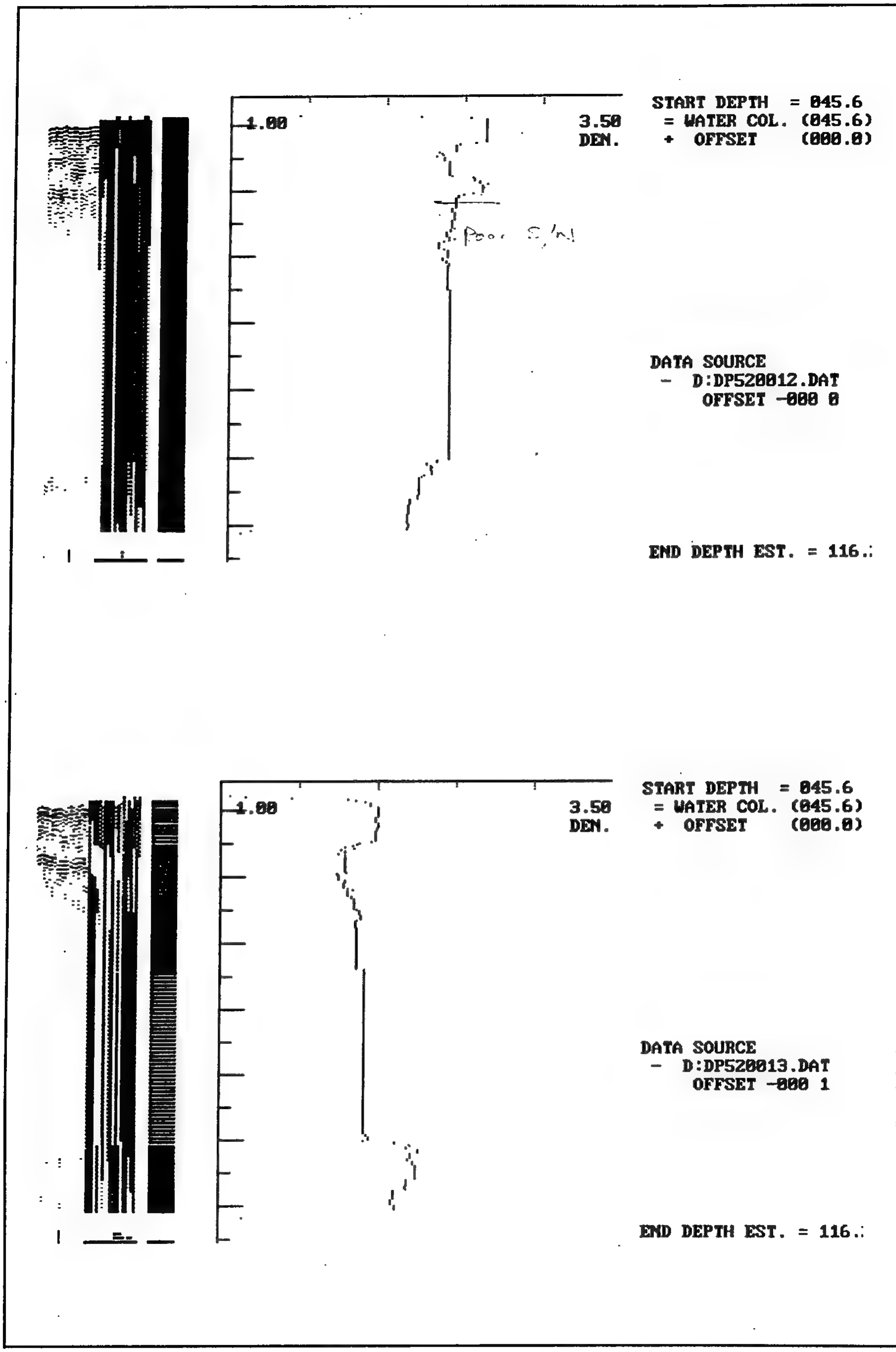
DEN.
START DEPTH = 045.6
= WATER COL. (045.6)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520009.DAT
OFFSET -000 3
END DEPTH EST. = 116.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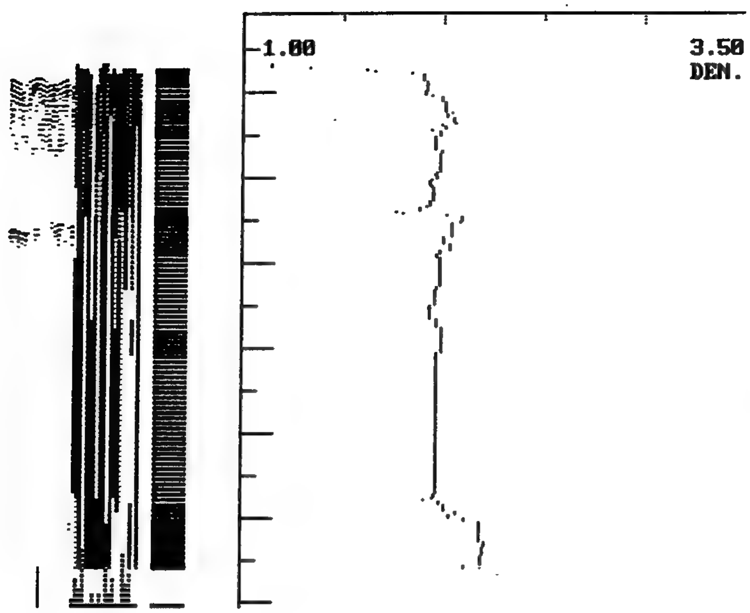
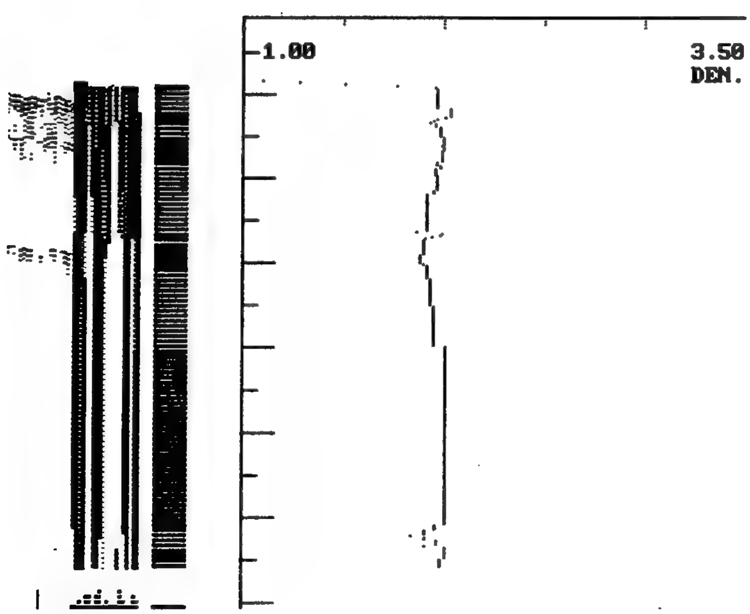
DEN.
START DEPTH = 045.6
= WATER COL. (045.6)
+ OFFSET (000.0)
Poor S/N
DATA SOURCE
- D:DP520012.DAT
OFFSET -000 0
END DEPTH EST. = 116.
1.00
3.50
DEN.
START DEPTH = 045.6
= WATER COL. (045.6)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520013.DAT
OFFSET -000 1
END DEPTH EST. = 116.



START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)

DATA SOURCE
- D:DP520015.DAT
OFFSET -000 4

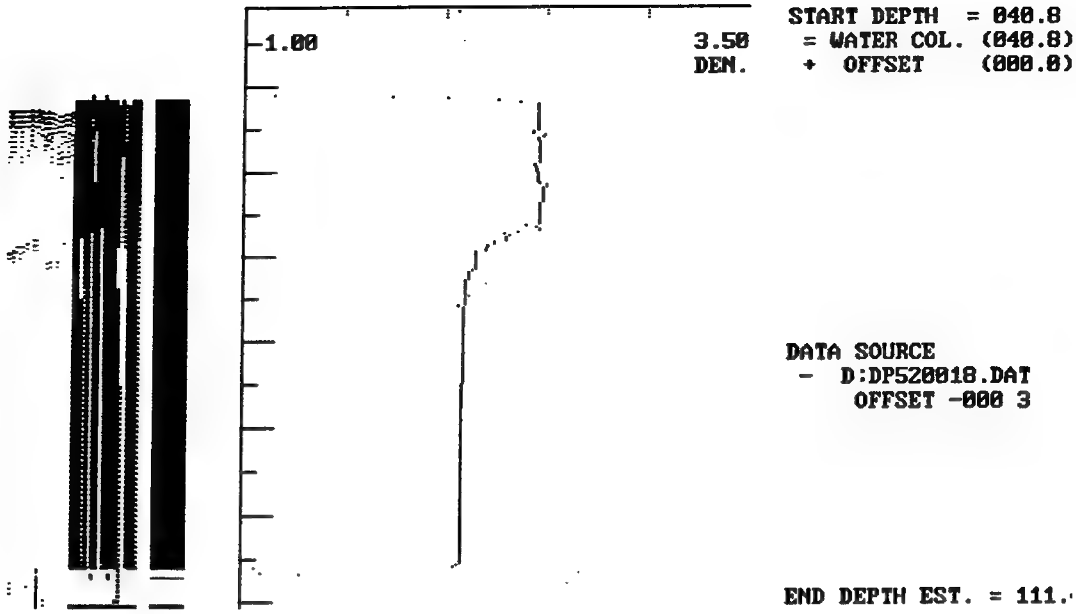
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)

DATA SOURCE
- D:DP520017.DAT
OFFSET -000 1

END DEPTH EST. = 111.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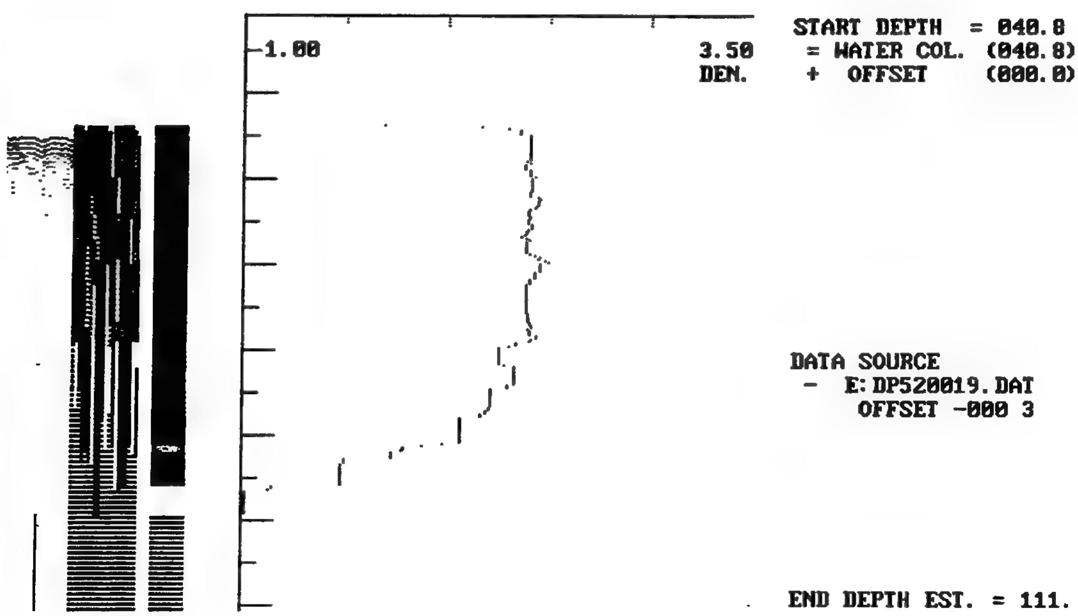
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520018.DAT
OFFSET -000 3
END DEPTH EST. = 111.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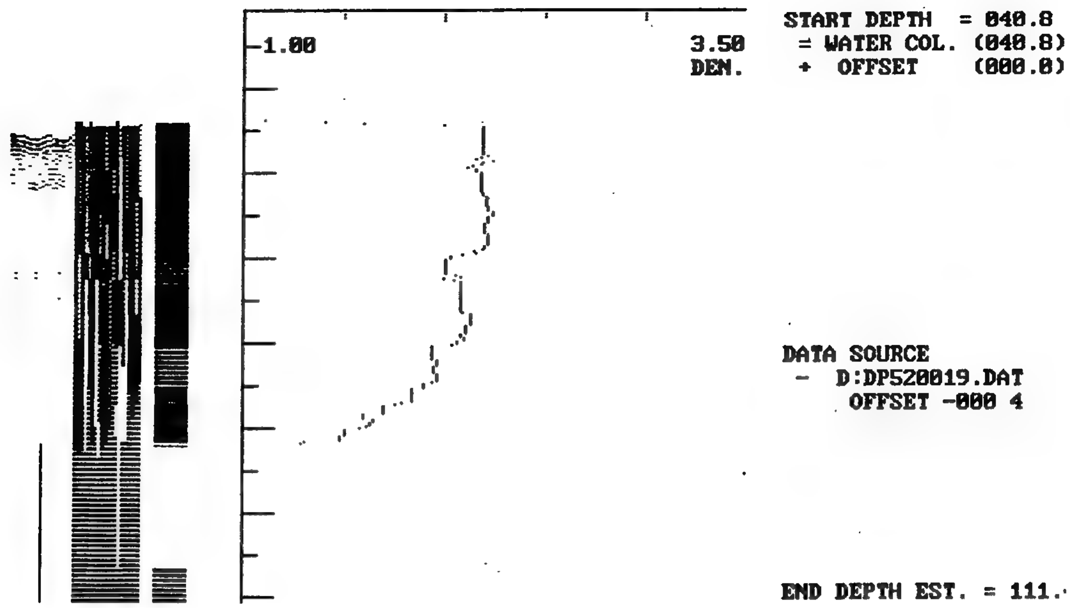
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- E:DP520019.DAT
OFFSET -000 3
END DEPTH EST. = 111.



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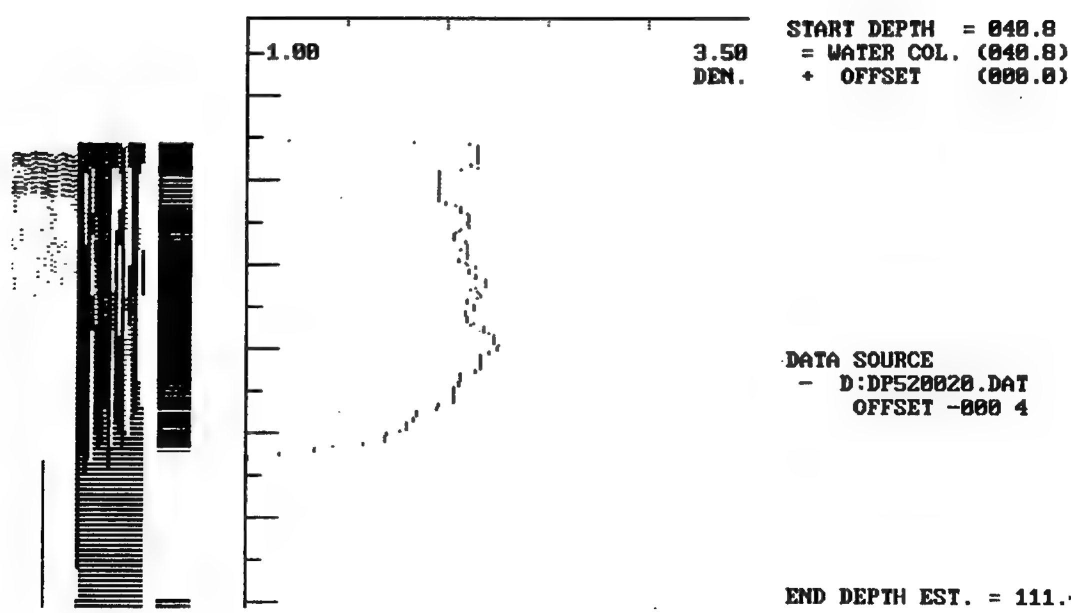
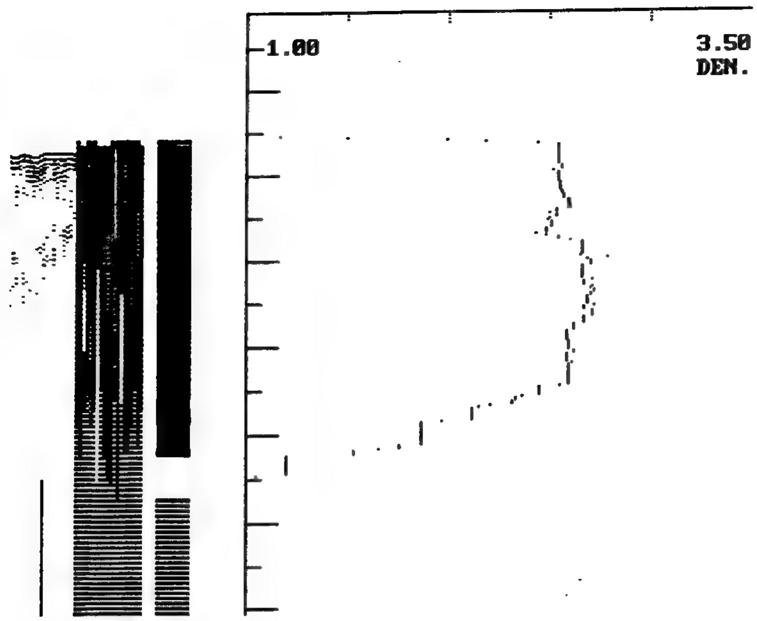
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520019.DAT
OFFSET -000 4
END DEPTH EST. = 111.



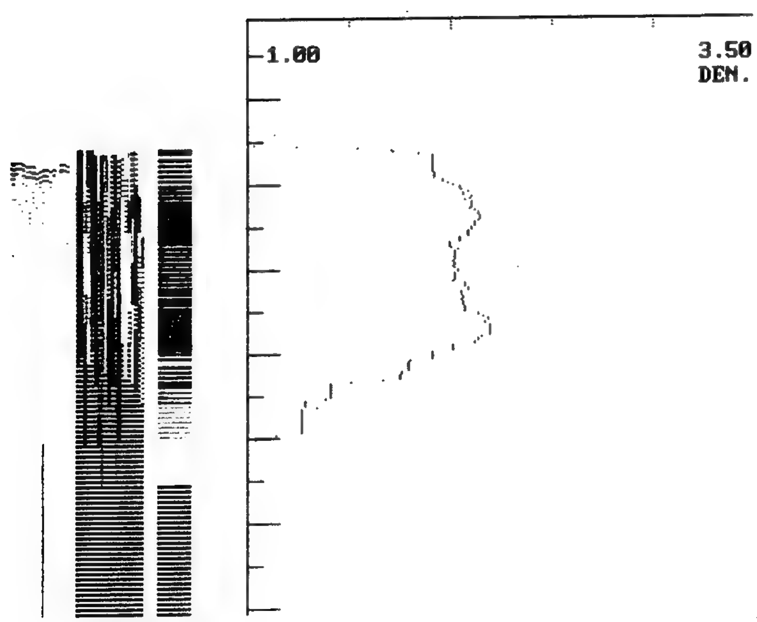
-1.00
3.50
DEN.
START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)
DATA SOURCE
- D:DP520020.DAT
OFFSET -000 4
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)

DATA SOURCE
- D:DP520021.DAT
OFFSET -000 3

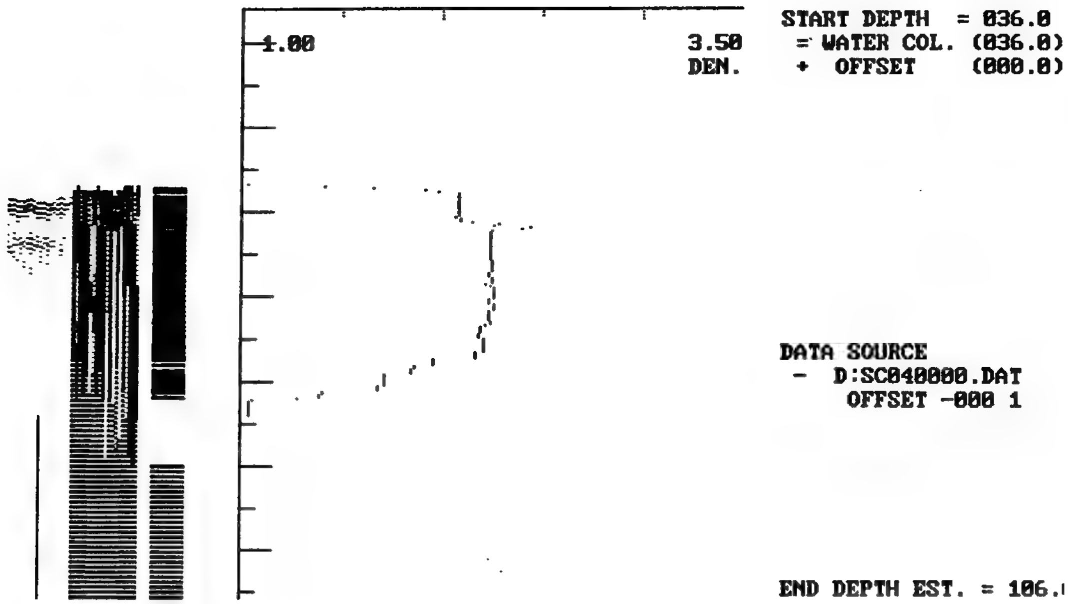
END DEPTH EST. = 111.



START DEPTH = 040.8
= WATER COL. (040.8)
+ OFFSET (000.0)

DATA SOURCE
- D:DP520021.DAT
OFFSET -000 5

END DEPTH EST. = 111.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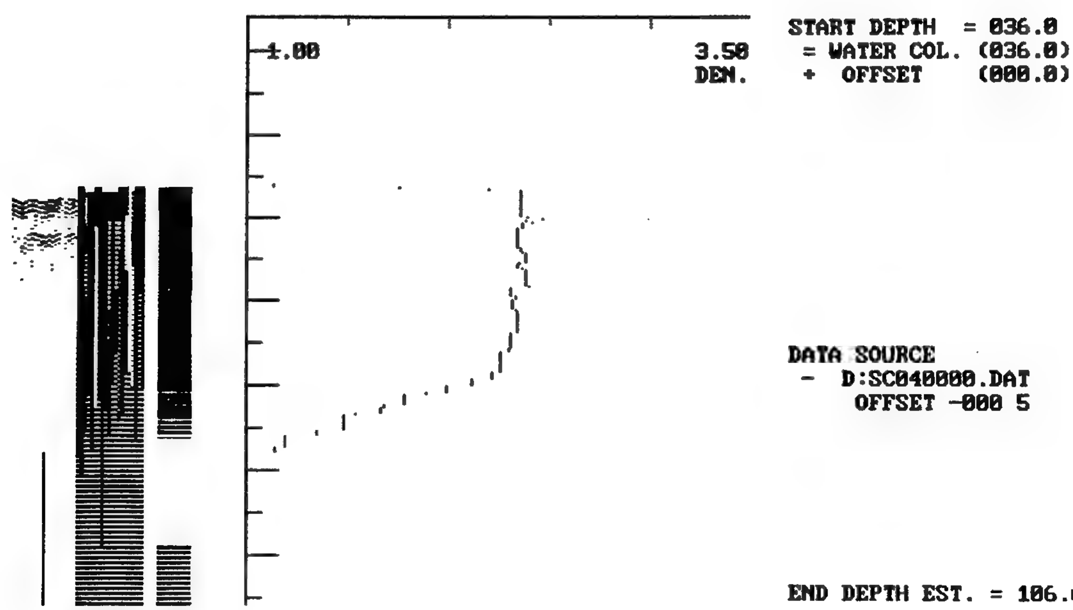
DEN.
START DEPTH = 036.0
= WATER COL. (036.0)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040000.DAT
OFFSET -000 1
END DEPTH EST. = 106.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DEN.
START DEPTH = 036.0
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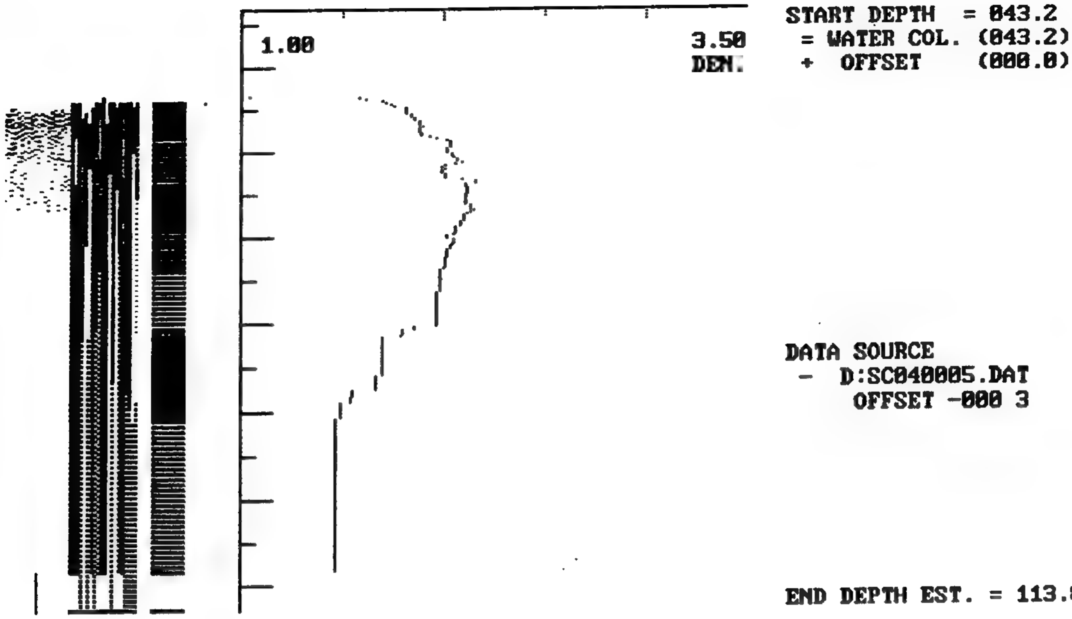
+ OFFSET (000.0)
DATA SOURCE
- D:SC040000.DAT
OFFSET -000 5
END DEPTH EST. = 106.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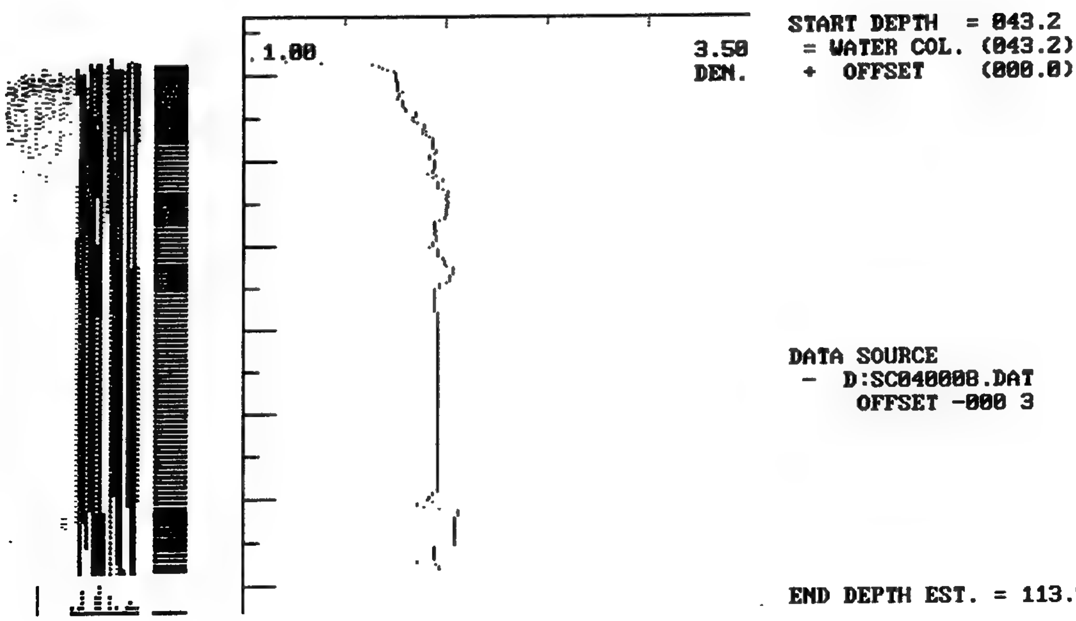
DEN.
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040005.DAT
OFFSET -000 3
END DEPTH EST. = 113.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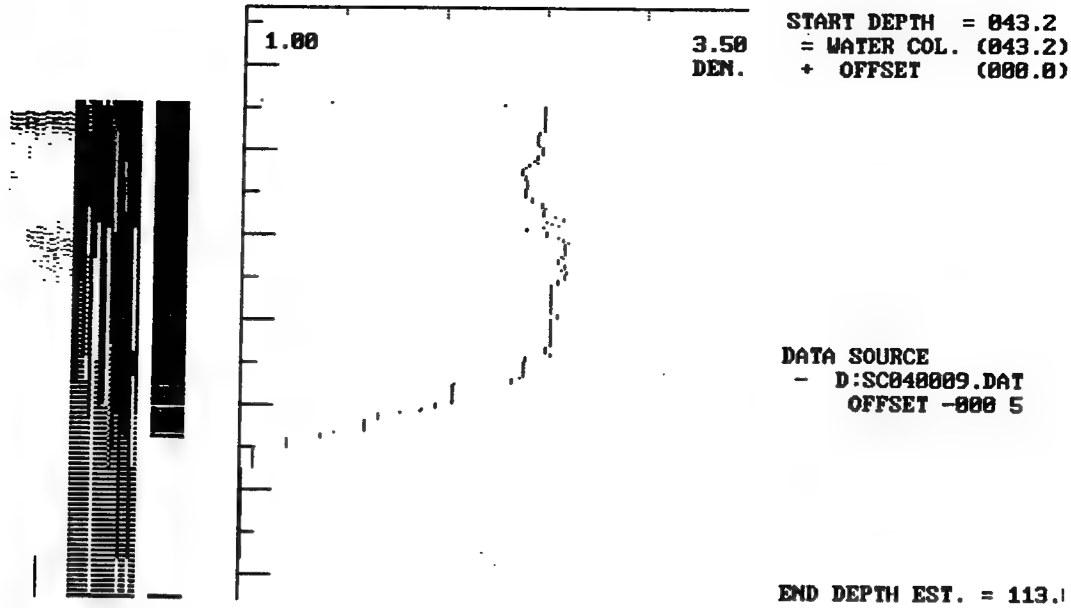
DEN.
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040008.DAT
OFFSET -000 3
END DEPTH EST. = 113.



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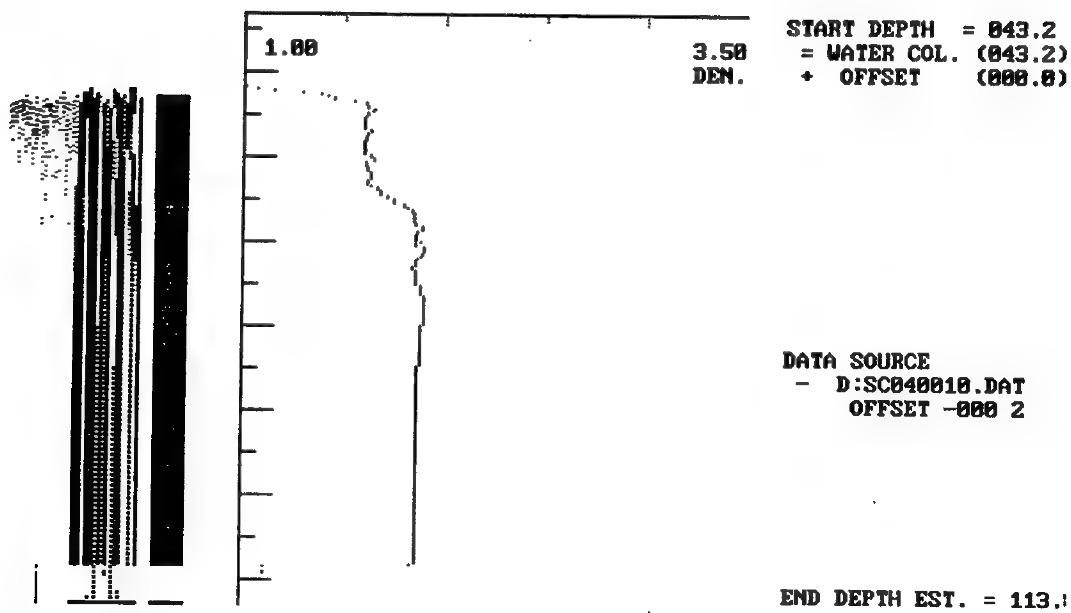
DEN.
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040009.DAT
OFFSET -000 5
END DEPTH EST. = 113.



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DEN.
START DEPTH = 043.2
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+ OFFSET (000.0)
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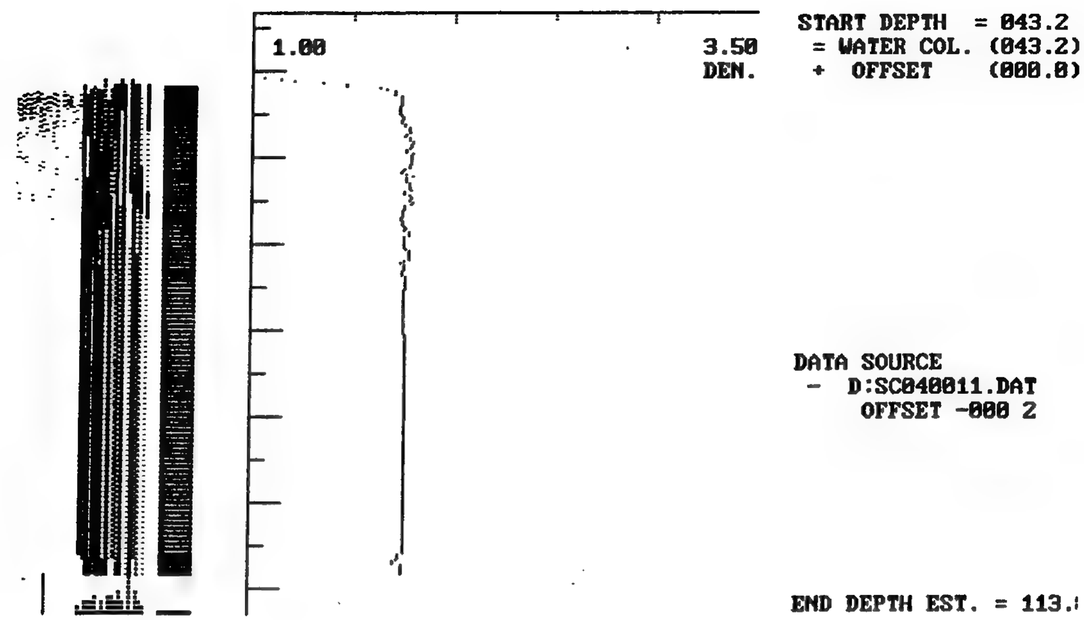
- D:SC040010.DAT
OFFSET -000 2
END DEPTH EST. = 113.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START DEPTH = 043.2
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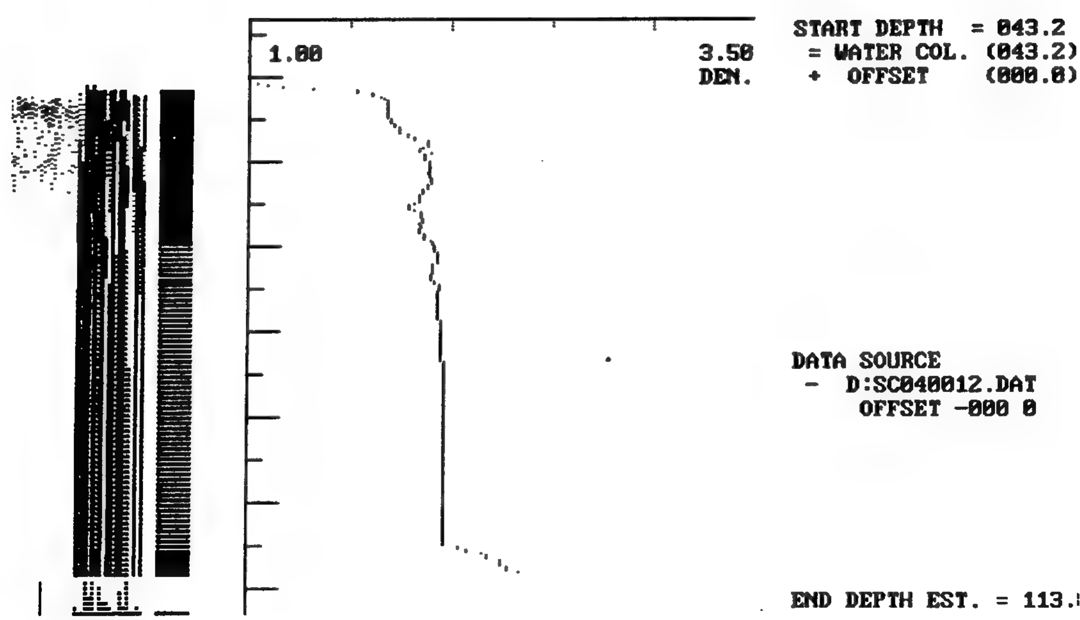
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DEN.
START DEPTH = 043.2
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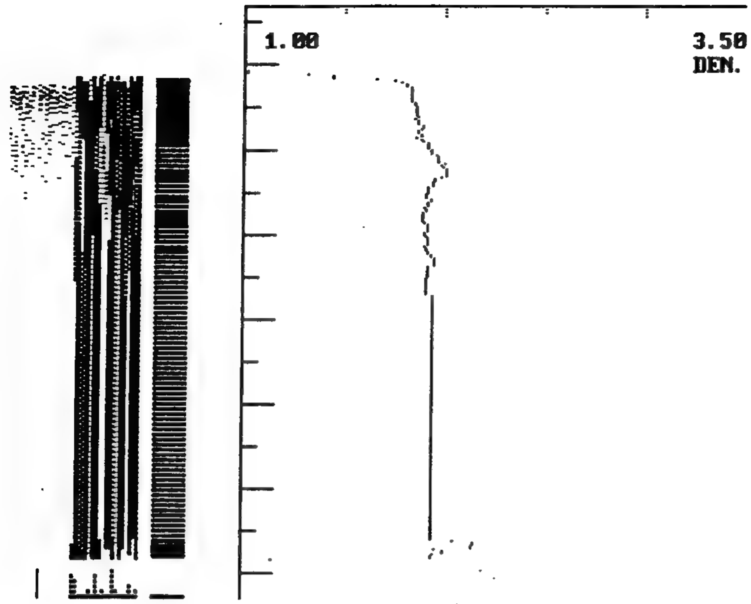
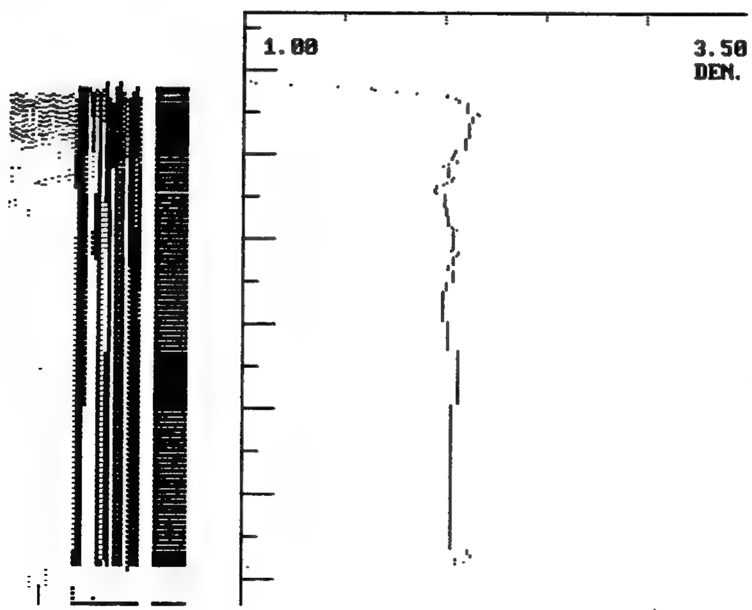
+ OFFSET (000.0)
DATA SOURCE
- D:SC040012.DAT
OFFSET -000 0
END DEPTH EST. = 113.



START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)

DATA SOURCE
- E:SC040013.DAT
OFFSET -000 0

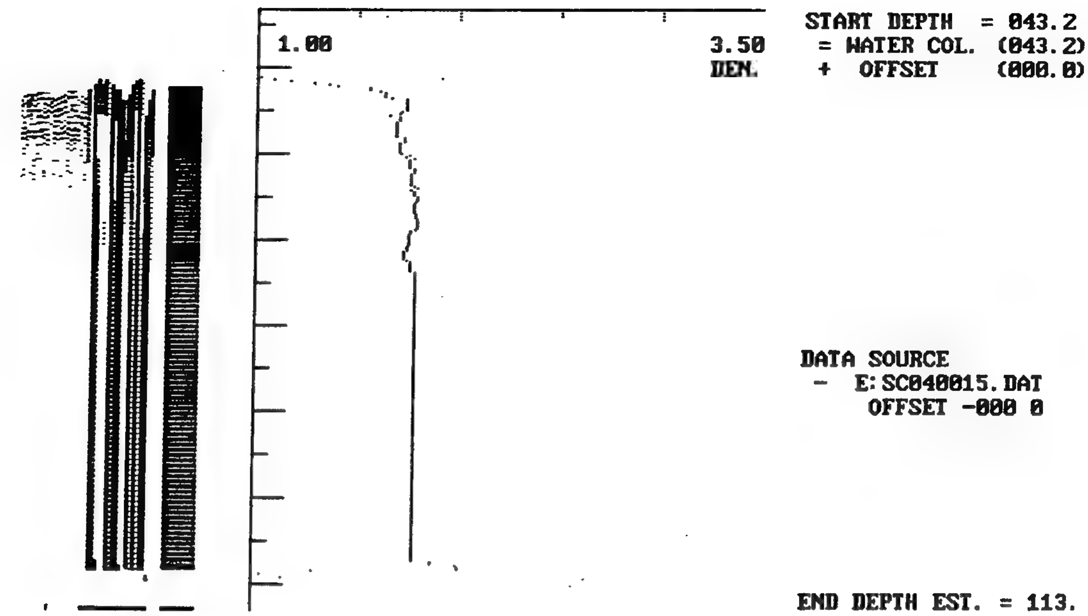
END DEPTH EST. = 113.



START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)

DATA SOURCE
- E:SC040014.DAT
OFFSET -000 0

END DEPTH EST. = 113.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START DEPTH = 043.2
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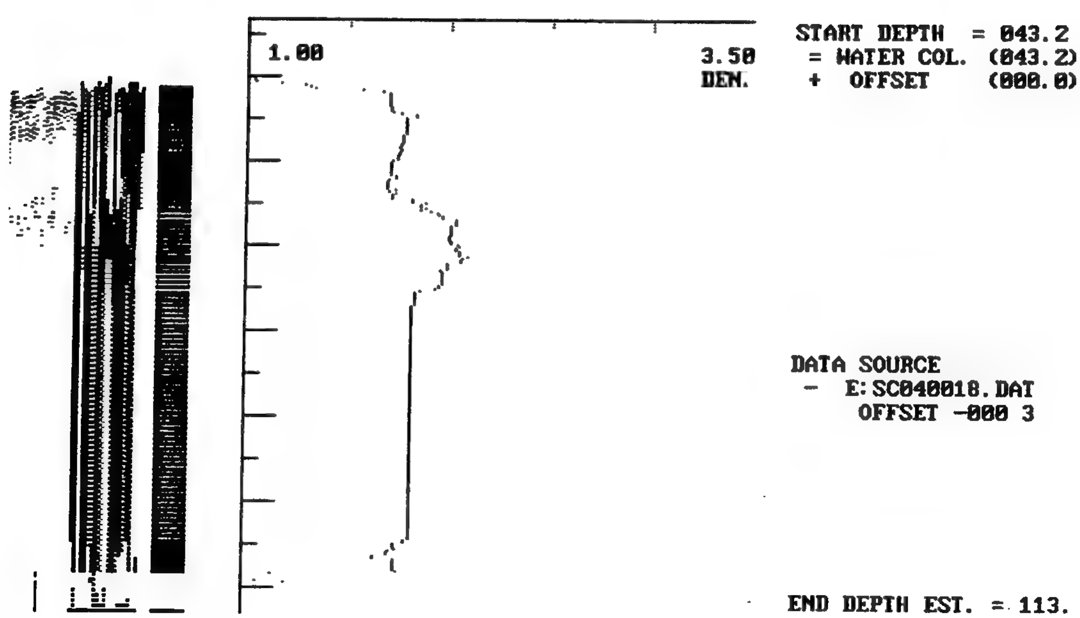
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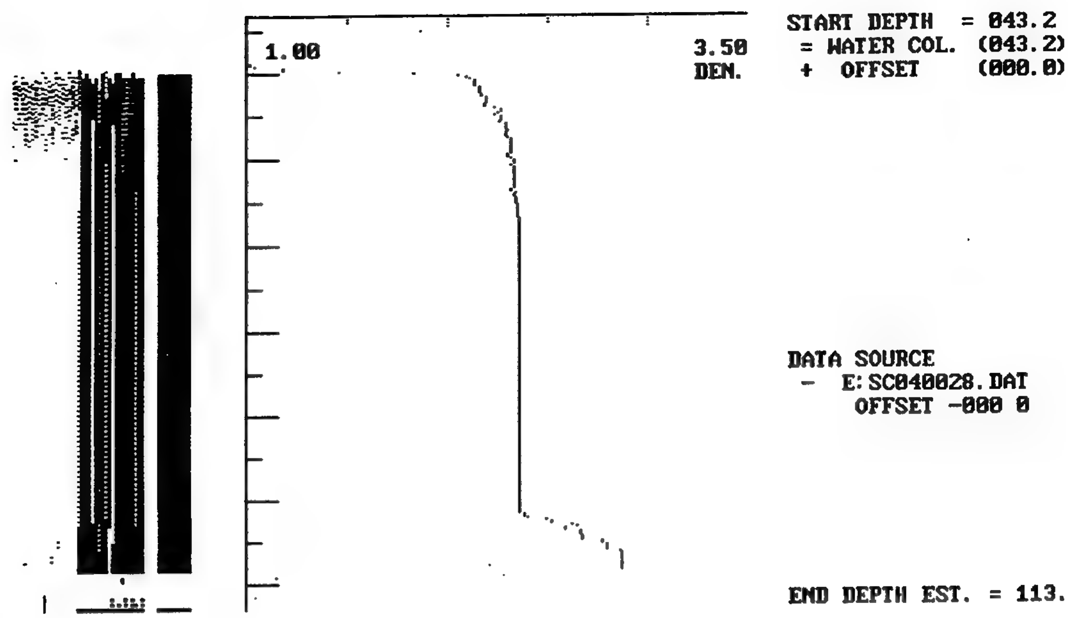
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+ OFFSET (000.0)
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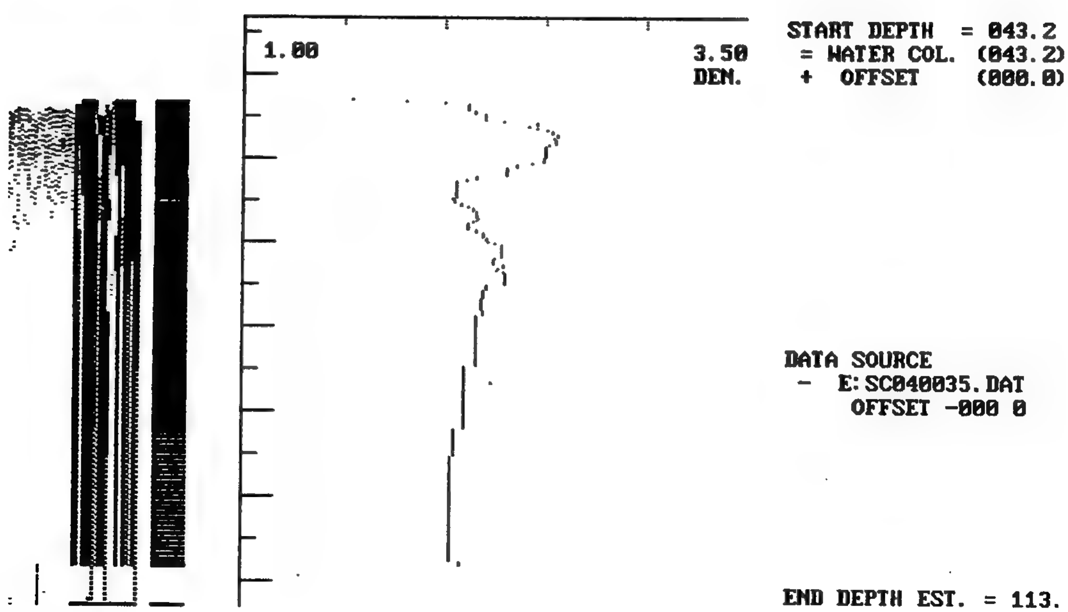
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START DEPTH = 043.2
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+ OFFSET (000.0)
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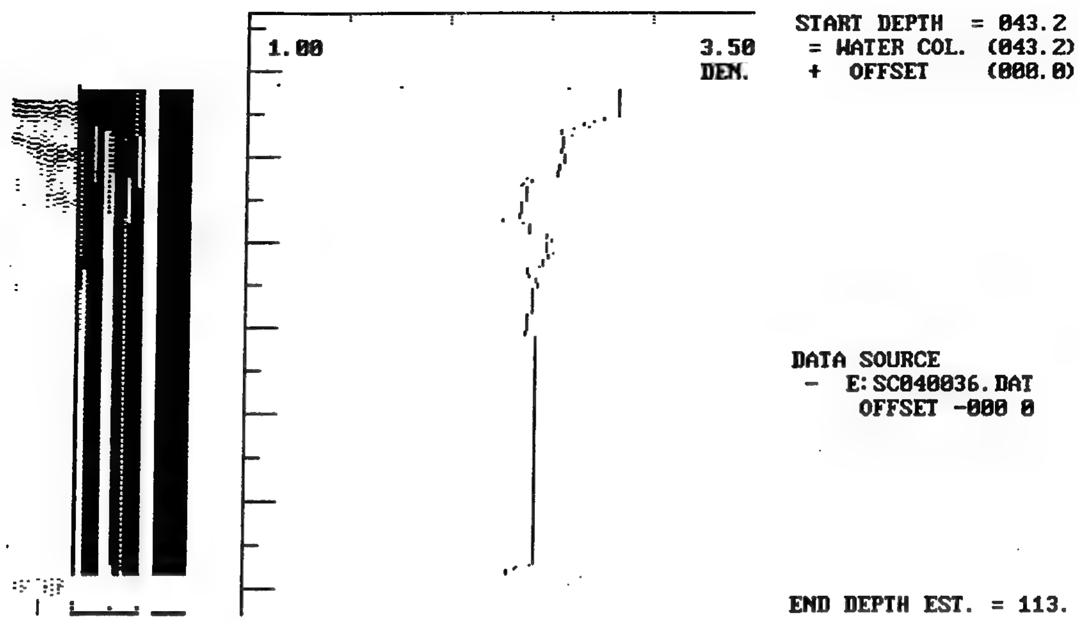
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START DEPTH = 043.2
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+ OFFSET (000.0)
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- E:SC040036.DAT
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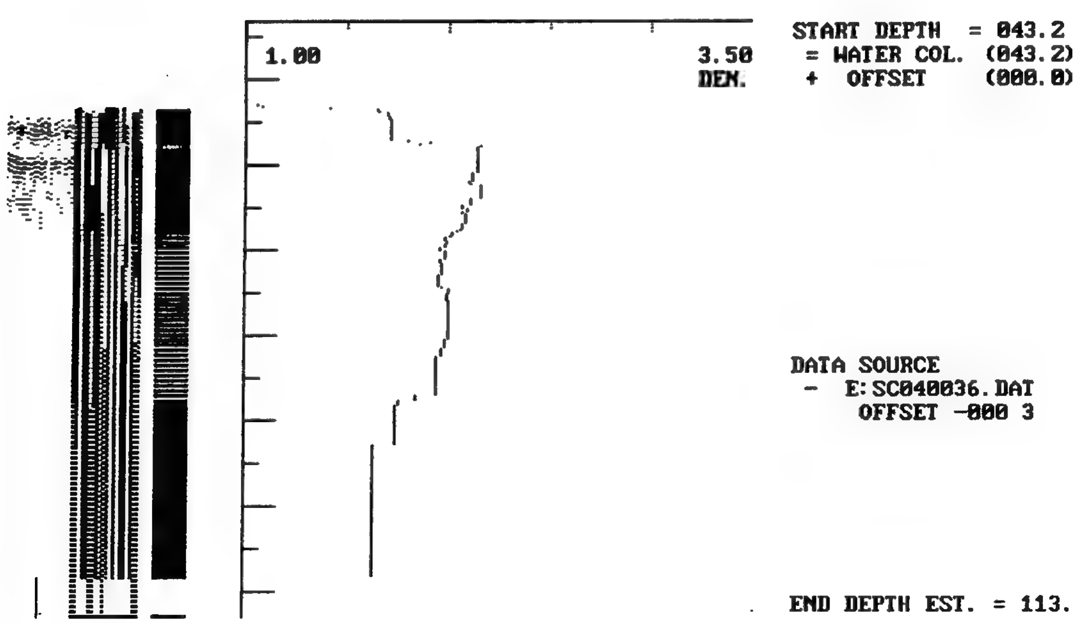
END DEPTH EST. = 113.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START DEPTH = 043.2
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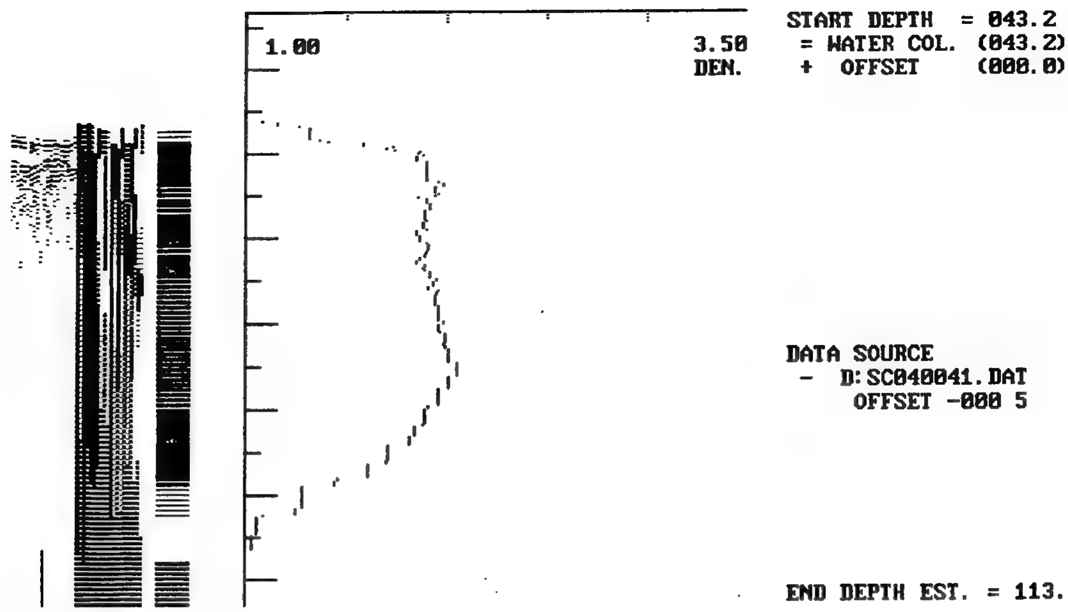
+ OFFSET (000.0)
DATA SOURCE
- E:SC040036.DAT
OFFSET -000 3
END DEPTH EST. = 113.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START DEPTH = 043.2
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+ OFFSET (000.0)
DATA SOURCE
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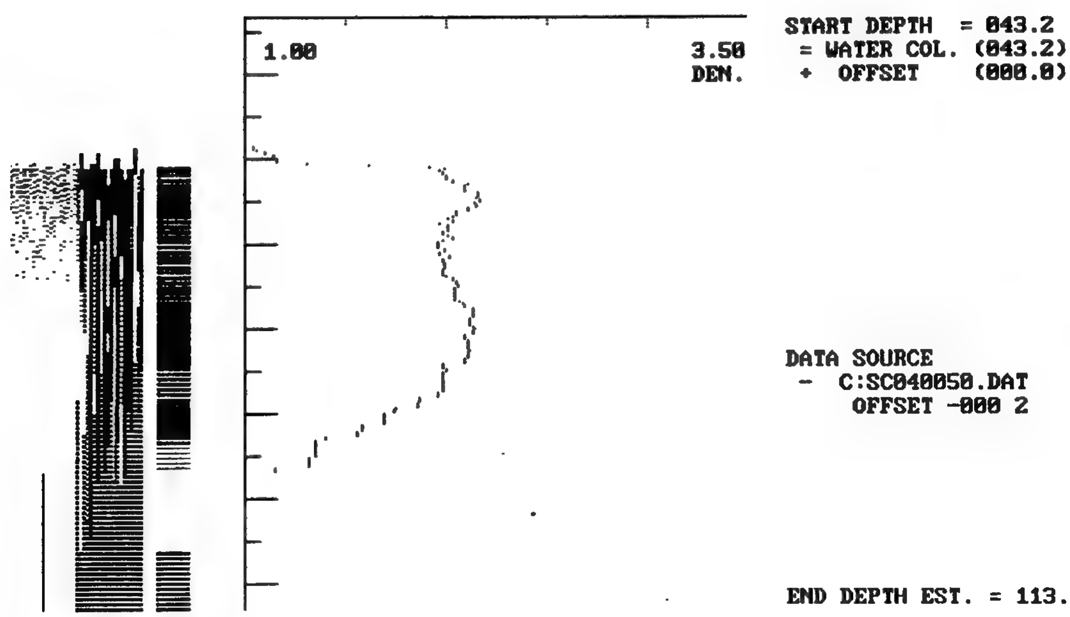
OFFSET -000 5
END DEPTH EST. = 113.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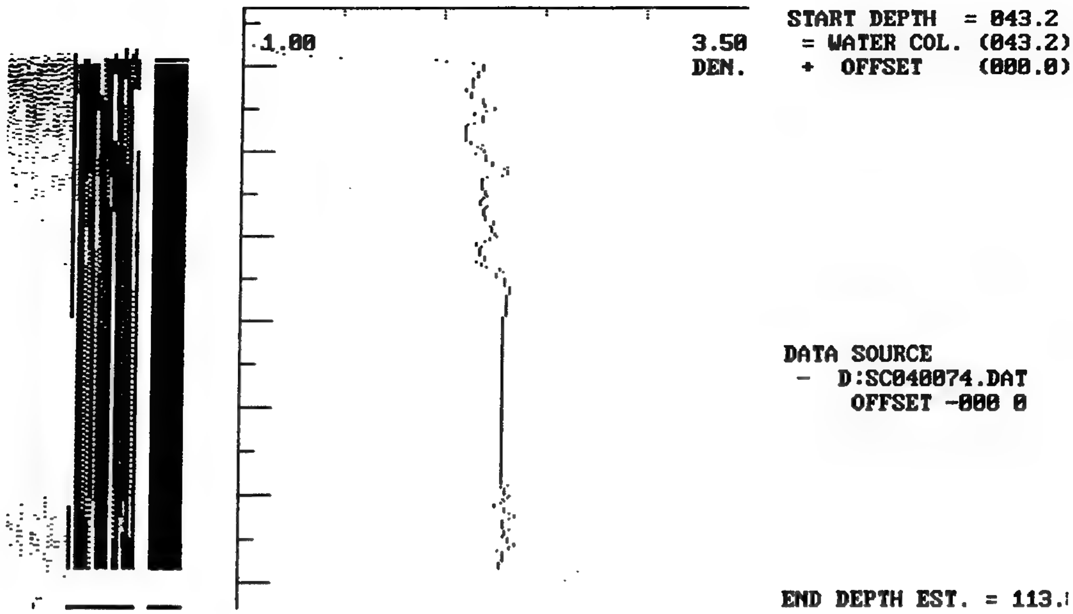
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- C:SC040050.DAT
OFFSET -000 2
END DEPTH EST. = 113.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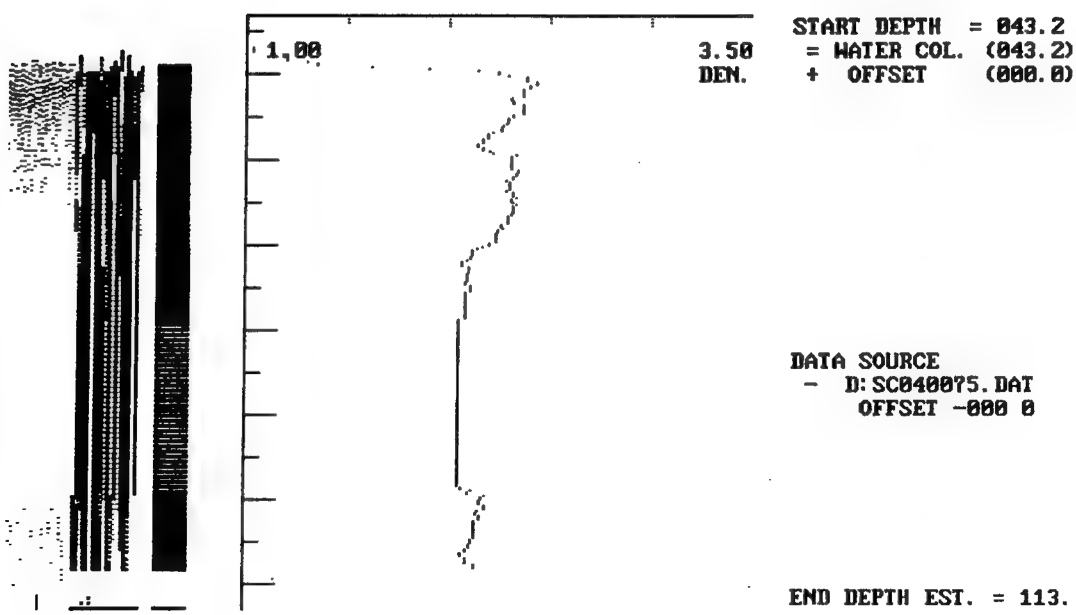
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040074.DAT
OFFSET -000 0
END DEPTH EST. = 113.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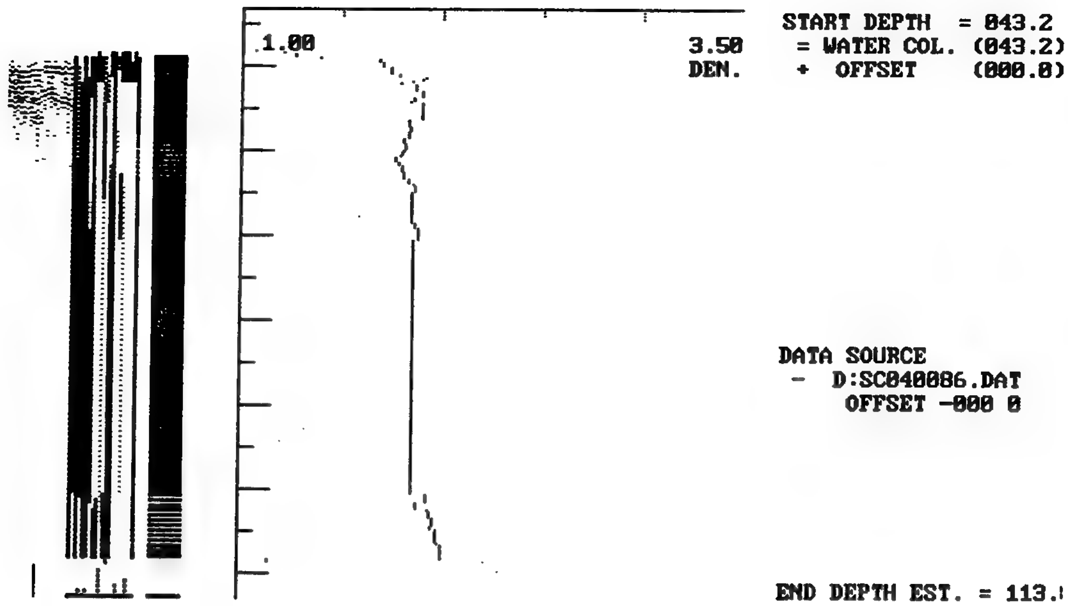
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040075.DAT
OFFSET -000 0
END DEPTH EST. = 113.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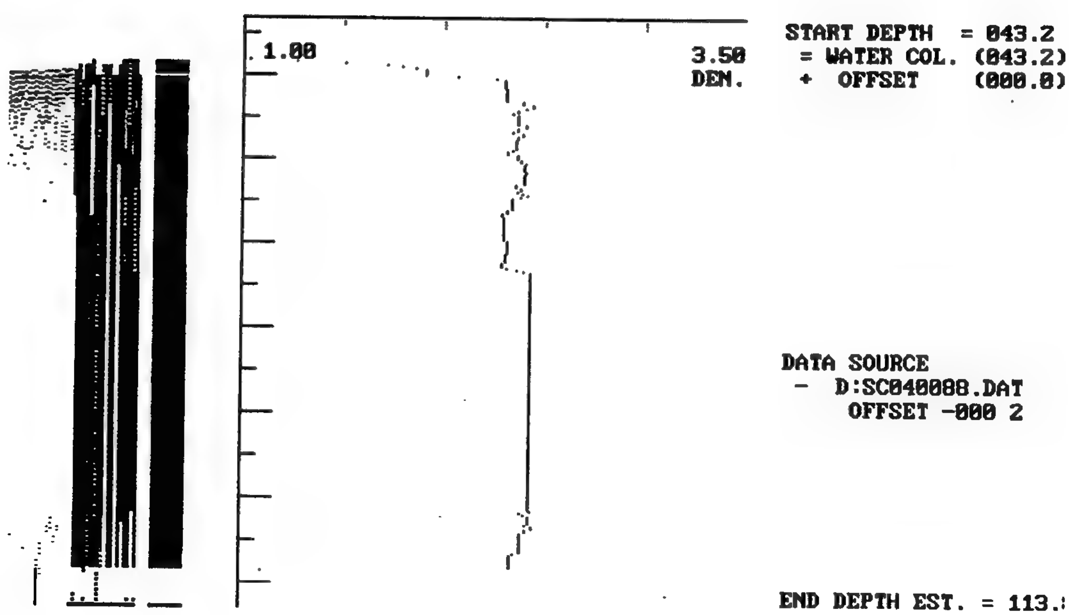
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040086.DAT
OFFSET -000 0
END DEPTH EST. = 113.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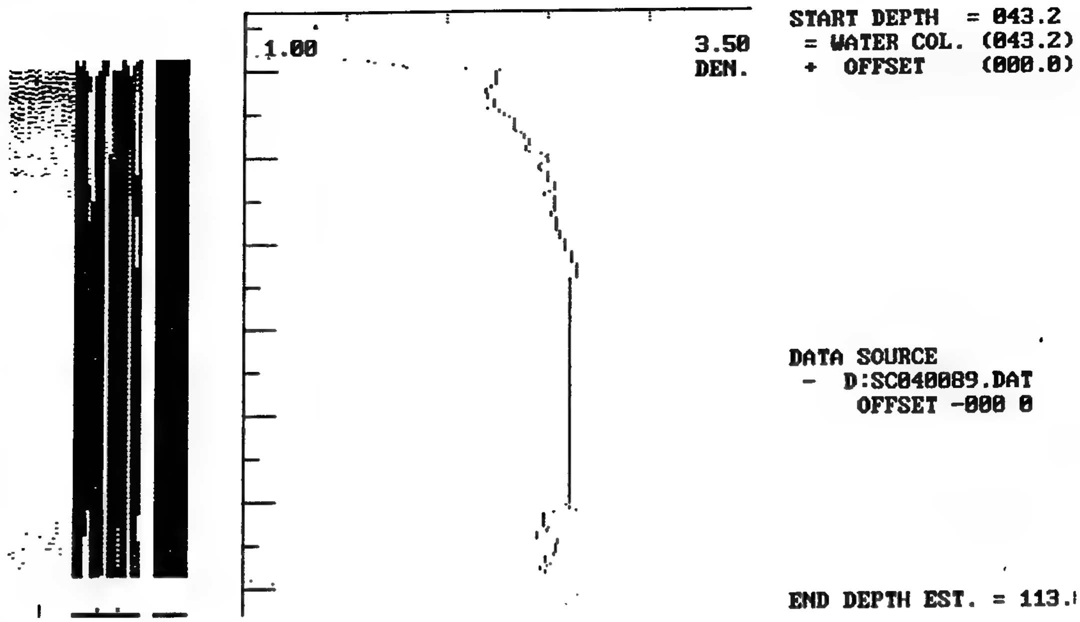
DEN.
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040088.DAT
OFFSET -000 2
END DEPTH EST. = 113.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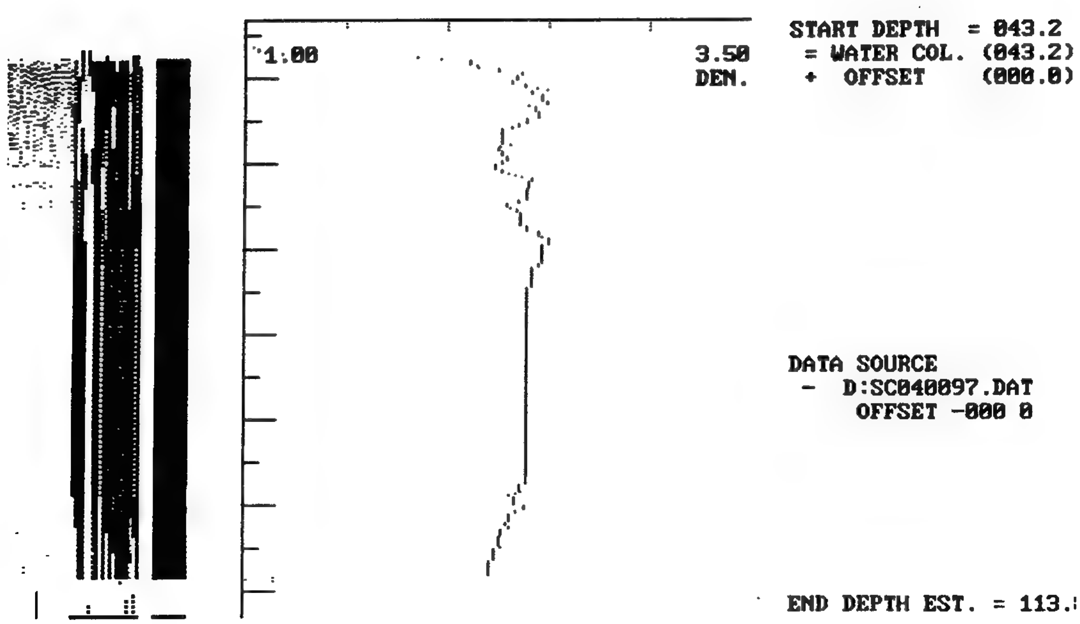
DEN.
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040089.DAT
OFFSET -000 0
END DEPTH EST. = 113.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START DEPTH = 043.2
= WATER COL. (043.2)
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DATA SOURCE
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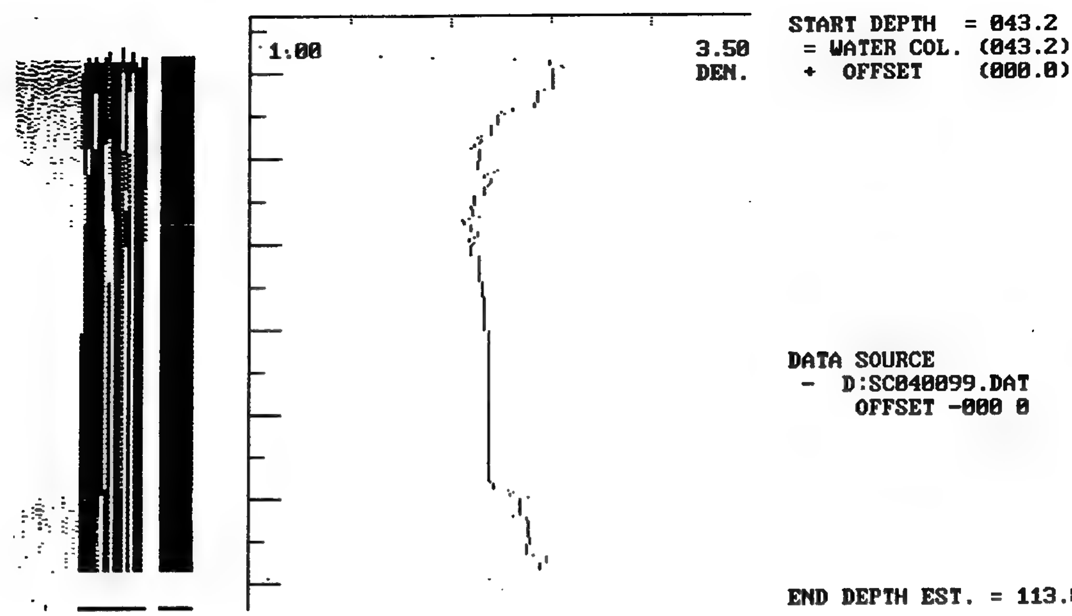
OFFSET -000 0
END DEPTH EST. = 113.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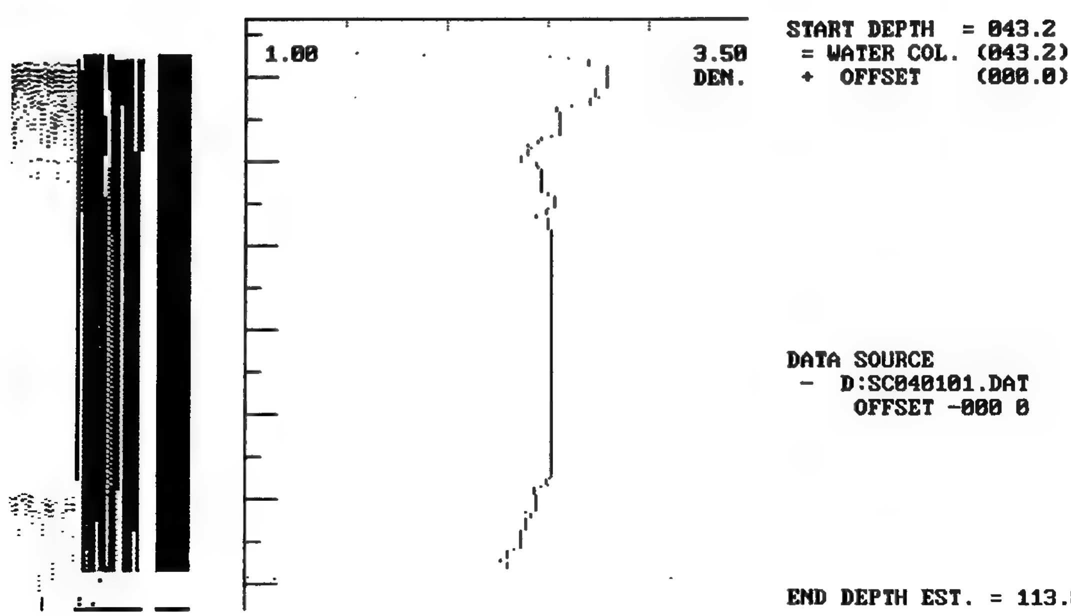
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040099.DAT
OFFSET -000 0
END DEPTH EST. = 113.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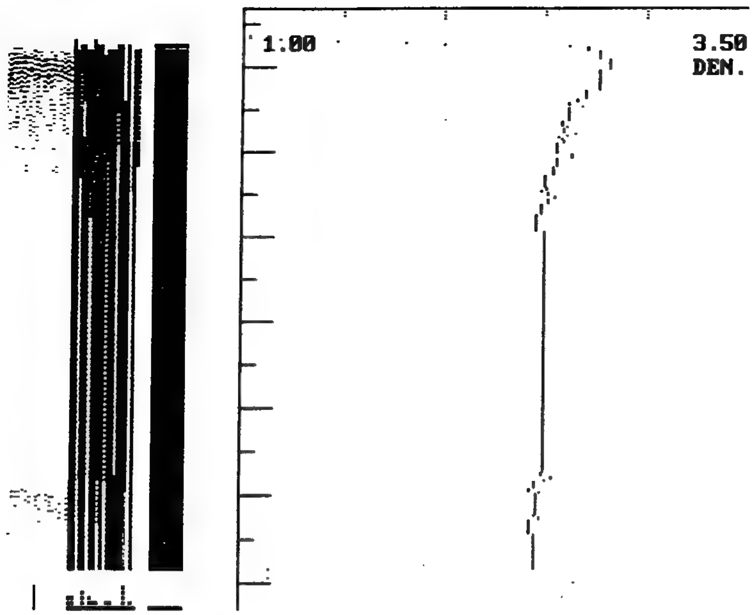
START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)
DATA SOURCE
- D:SC040101.DAT
OFFSET -000 0
END DEPTH EST. = 113.



START DEPTH = 043.2
= WATER COL. (043.2)
+ OFFSET (000.0)

DATA SOURCE
- D:SC040104.DAT
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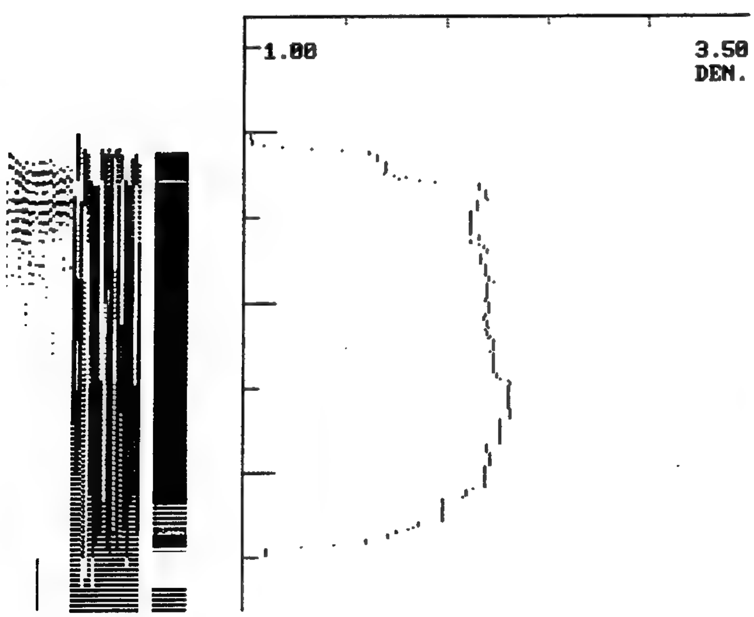
END DEPTH EST. = 113.!



START DEPTH = 043.2
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+ OFFSET (000.0)

DATA SOURCE
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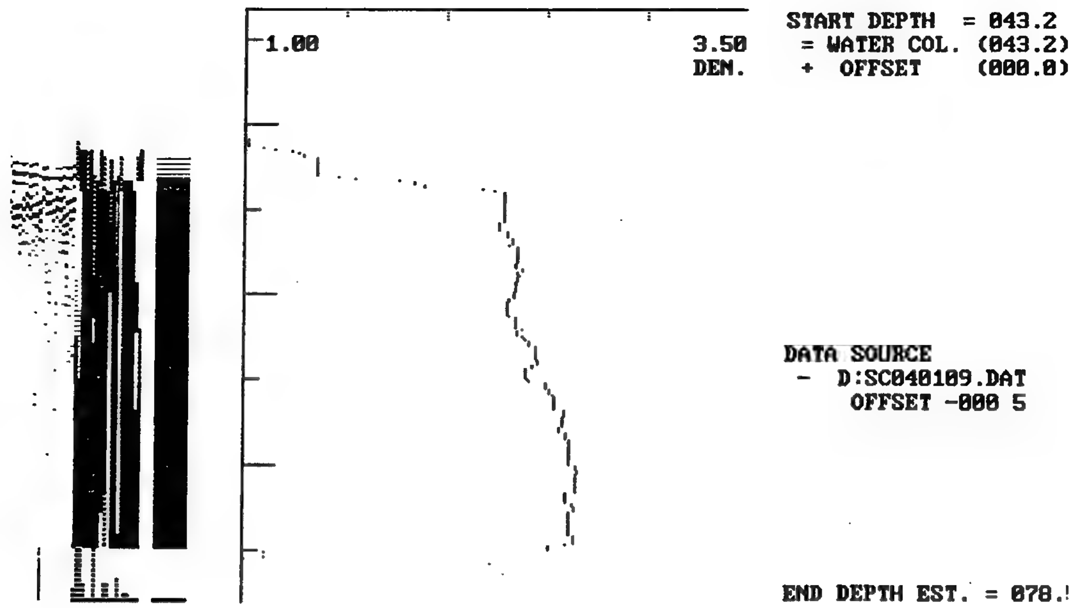
END DEPTH EST. = 078.!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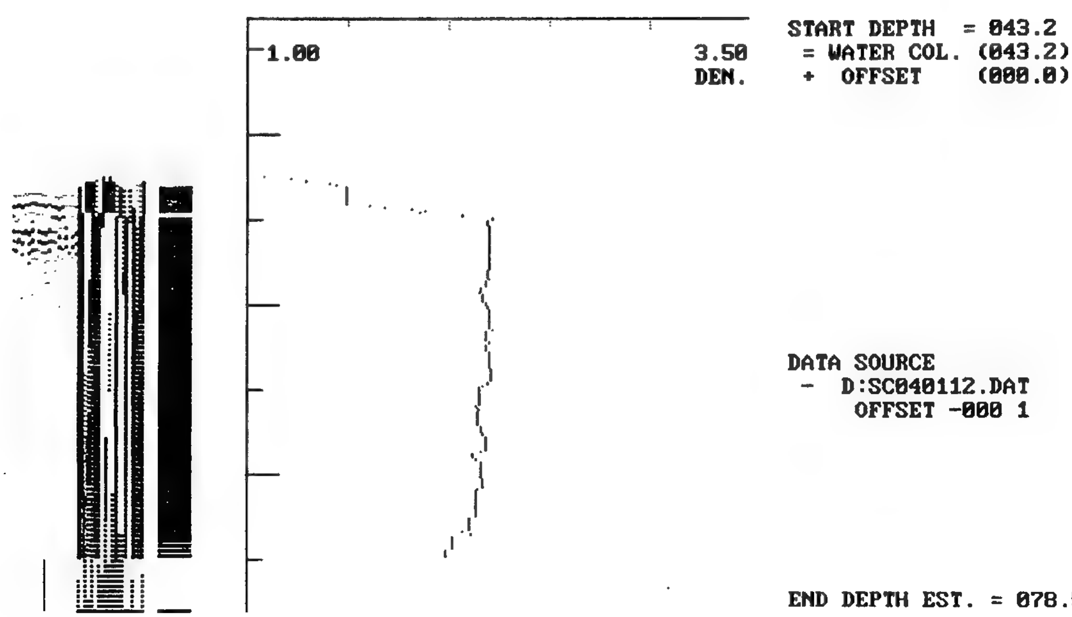
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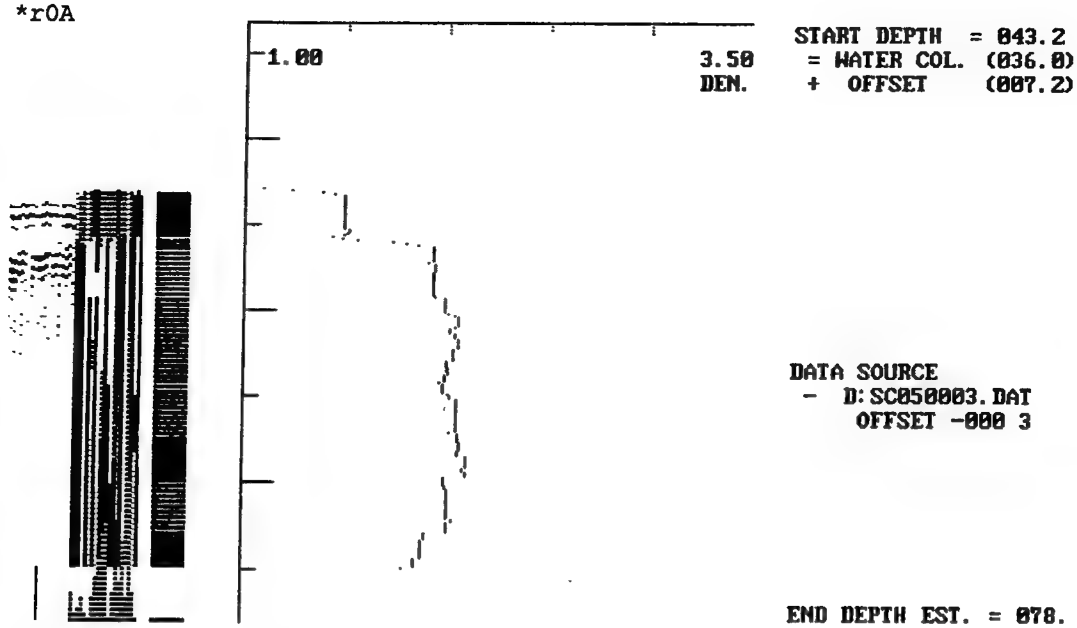
*r0A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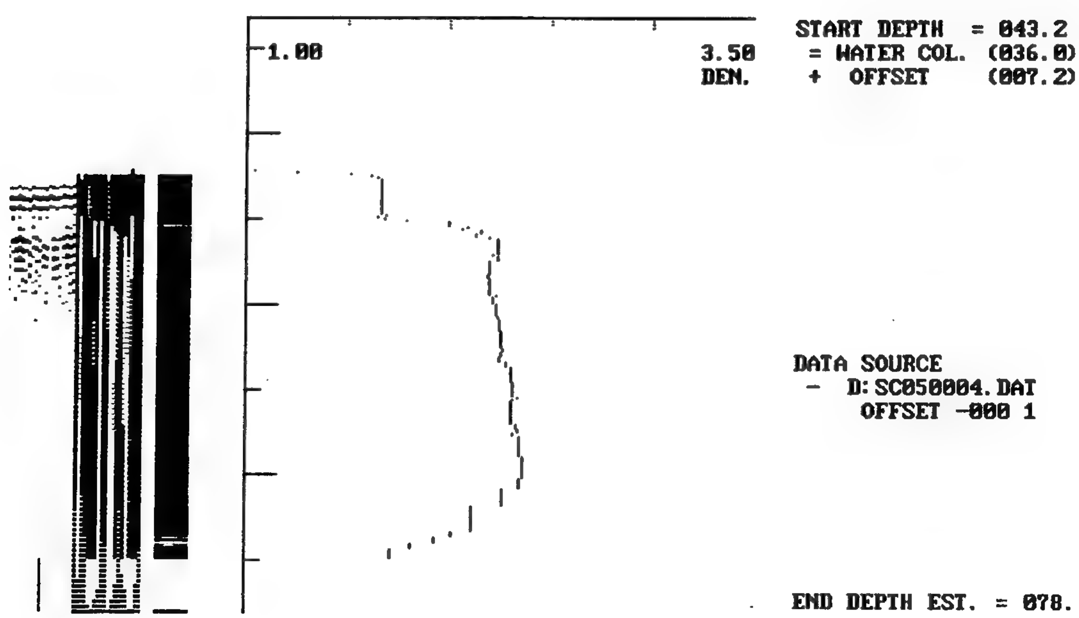
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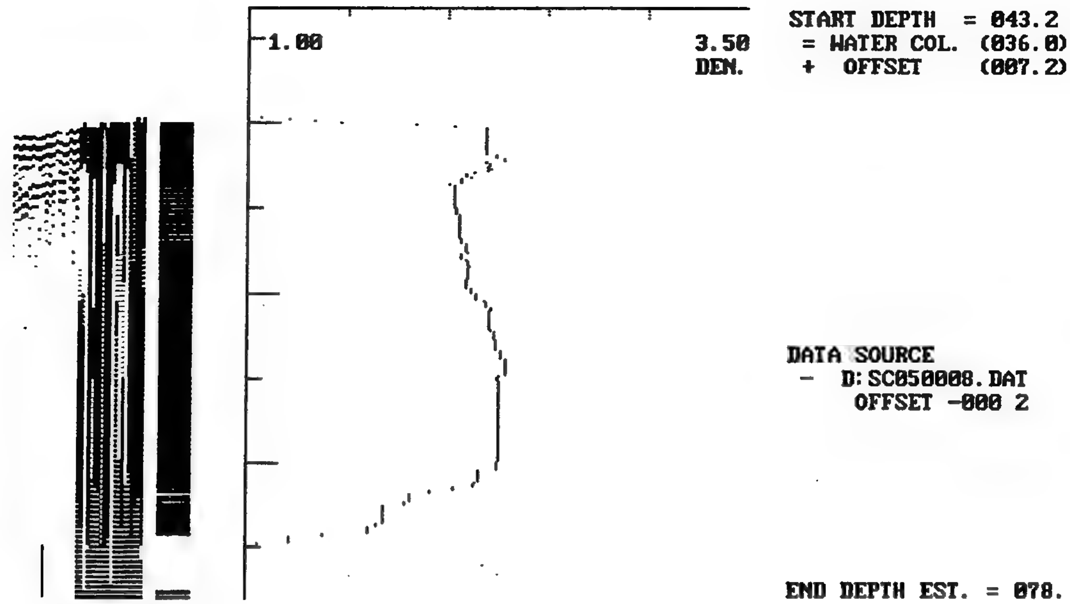
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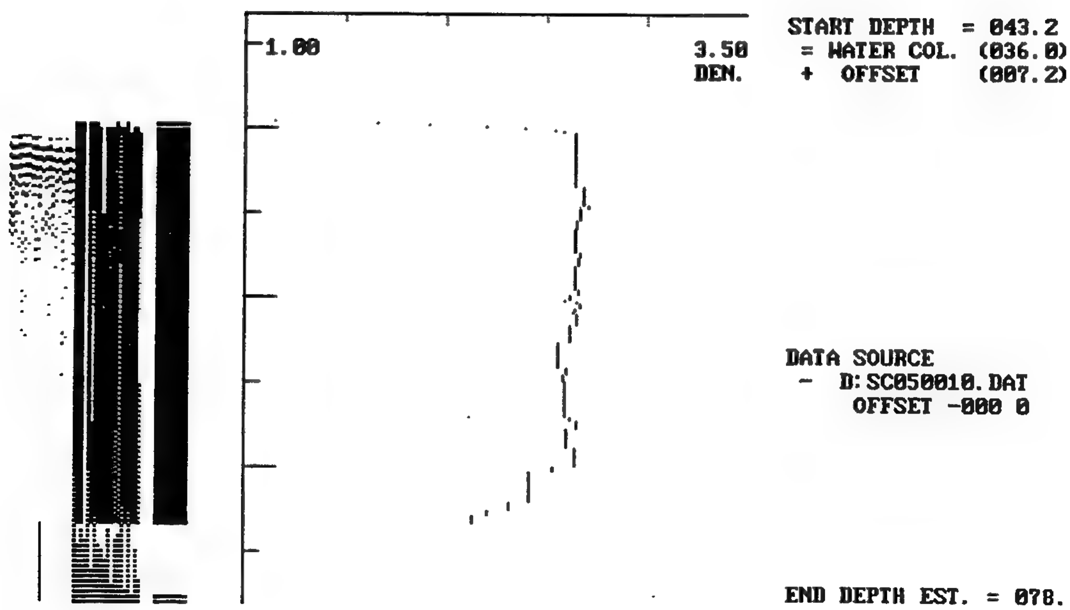
END DEPTH EST. = 078.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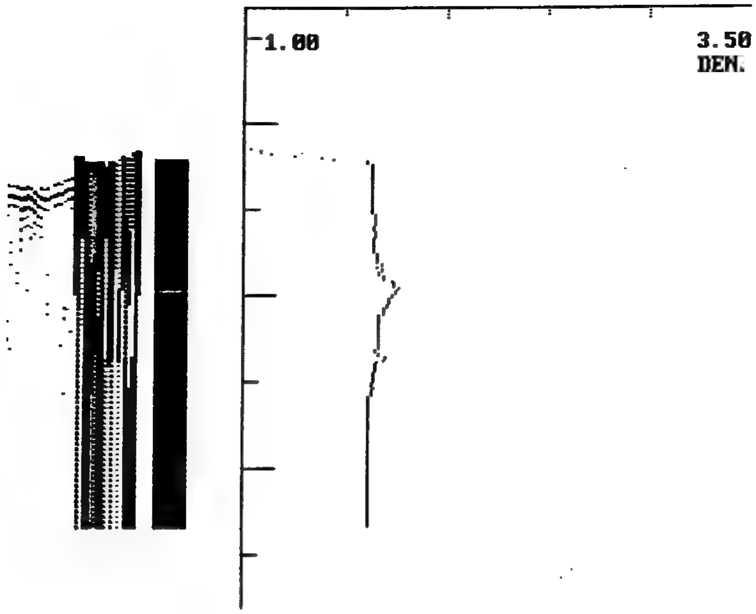

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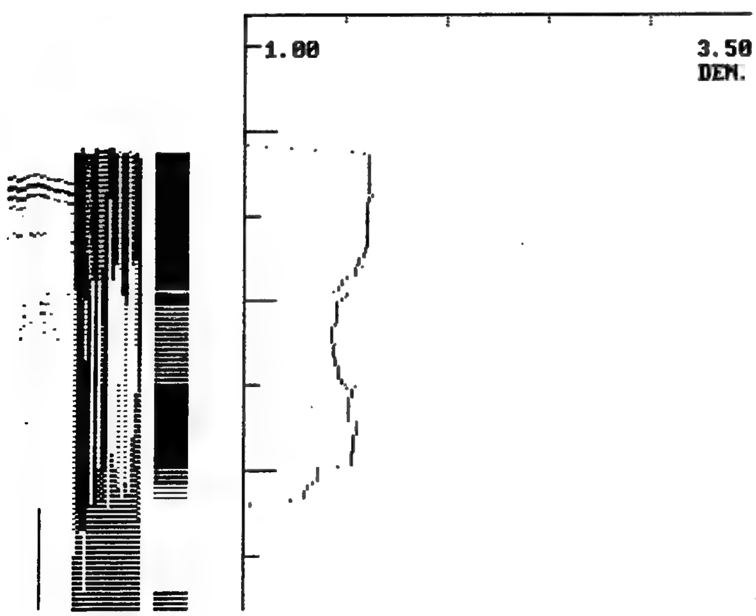

START DEPTH = 043.2
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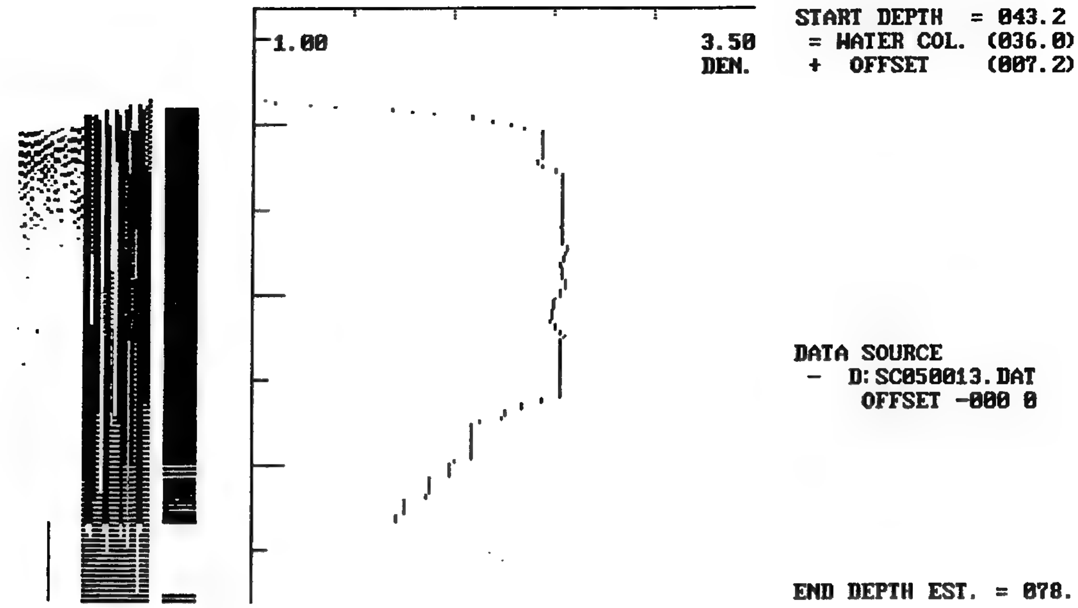
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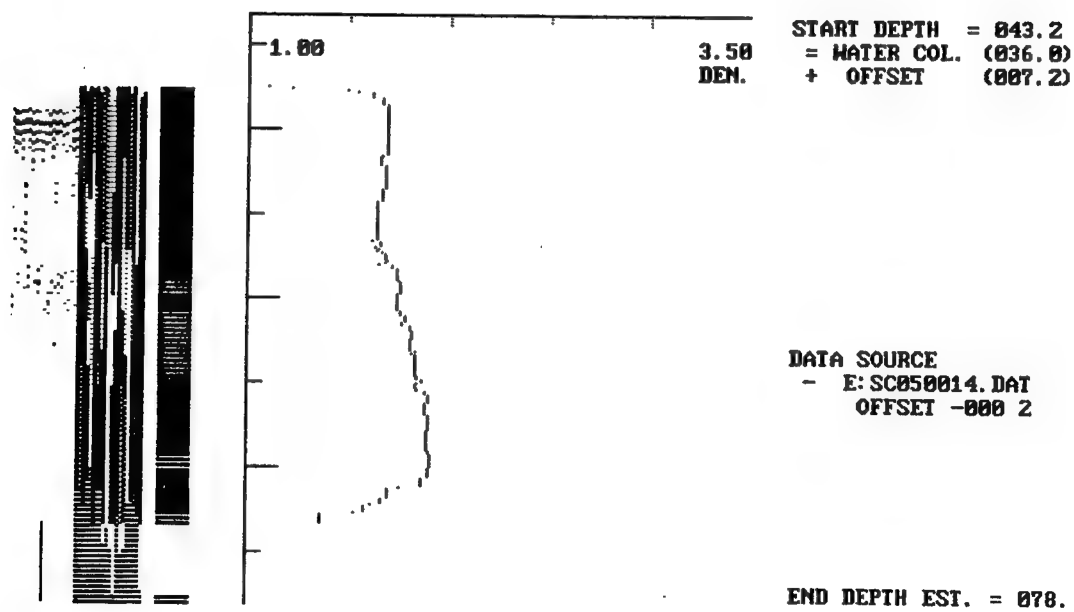
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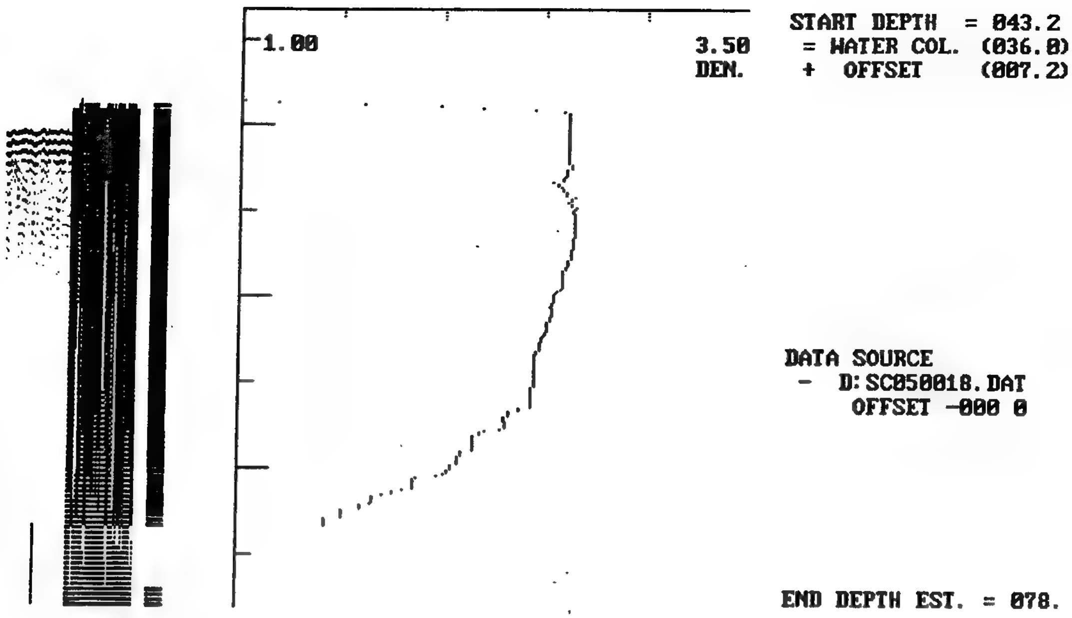
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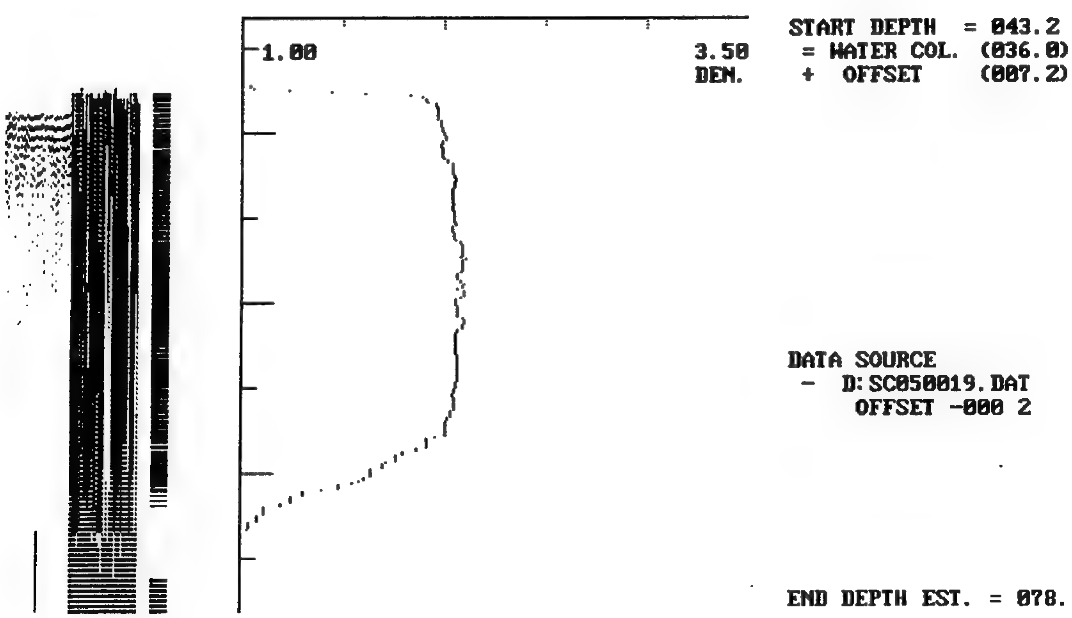
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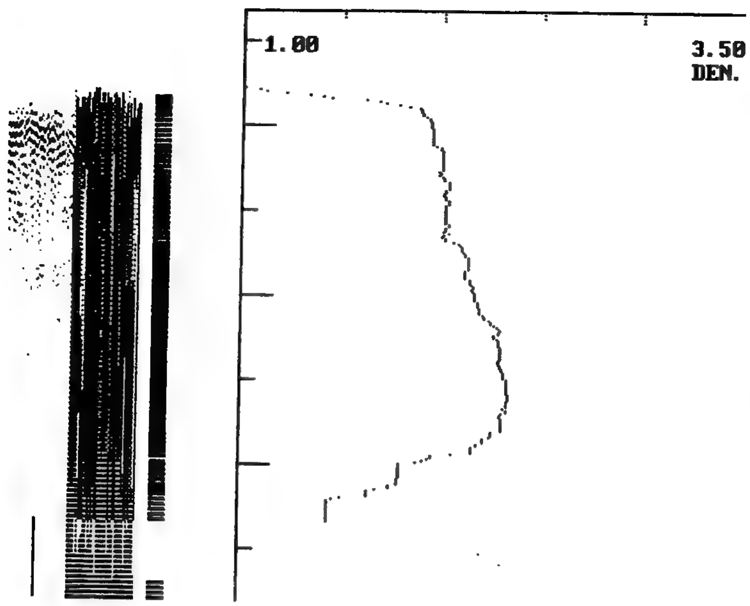

START DEPTH = 043.2
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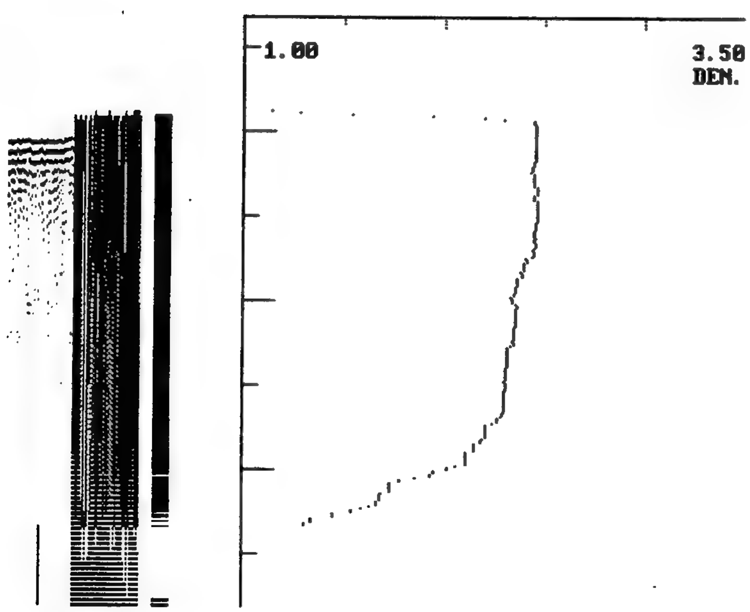
END DEPTH EST. = 078.



START DEPTH = 043.2
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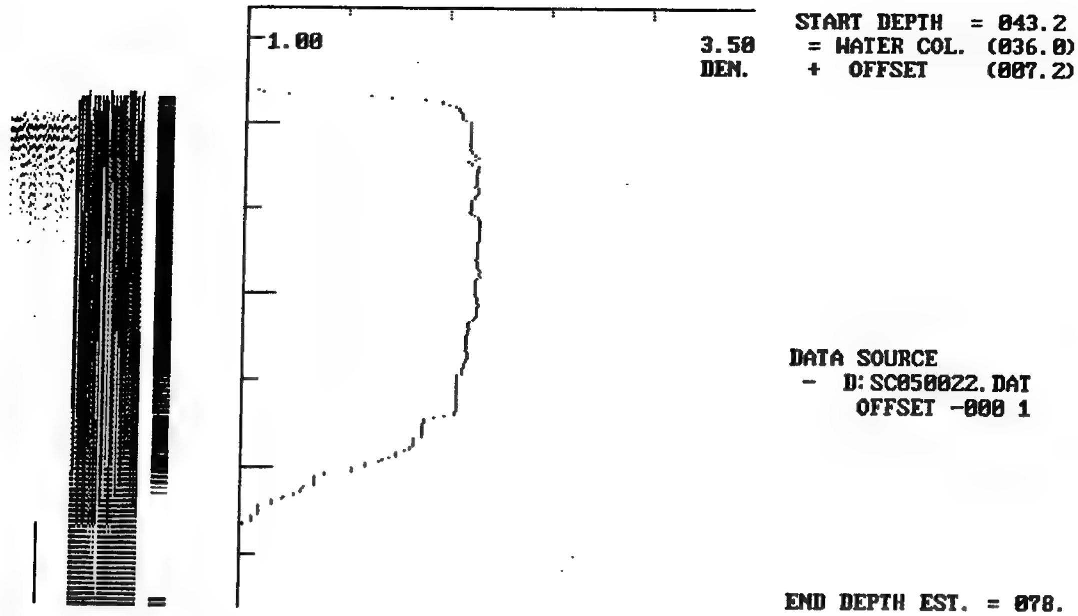
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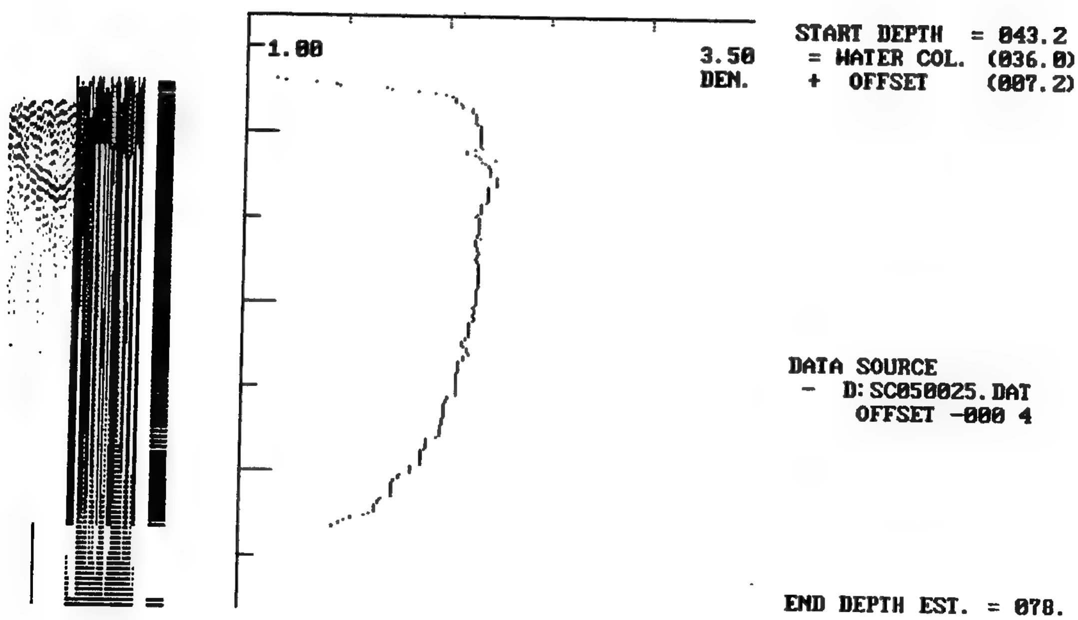
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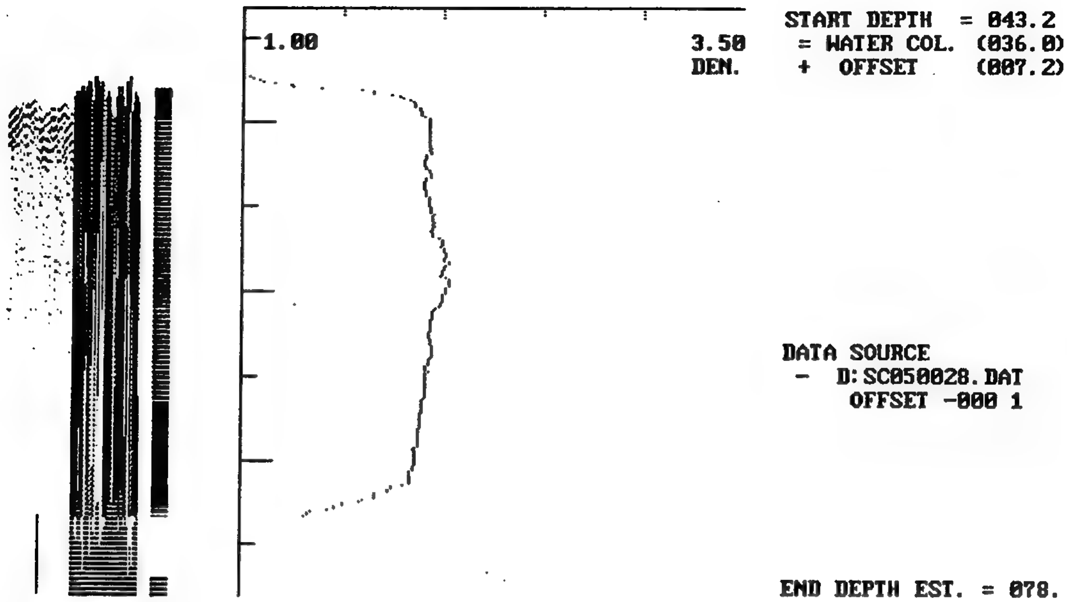
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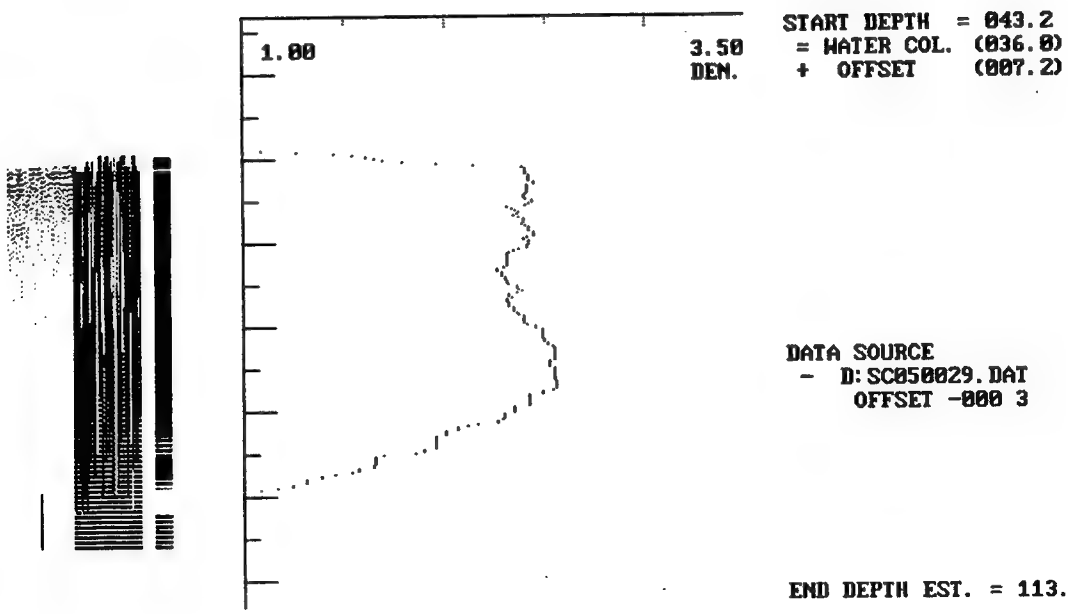
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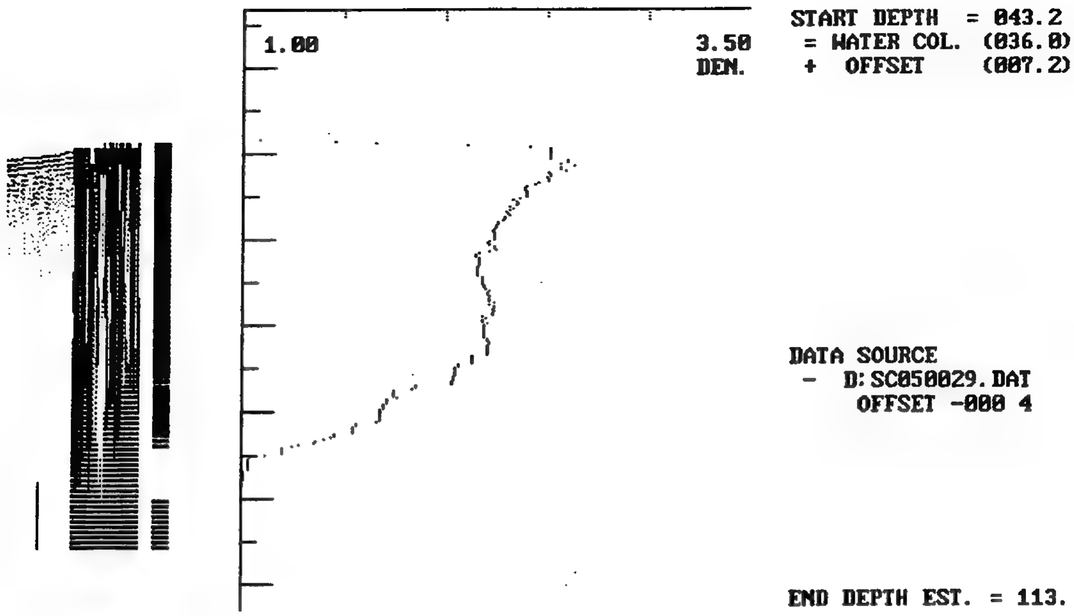
END DEPTH EST. = 113.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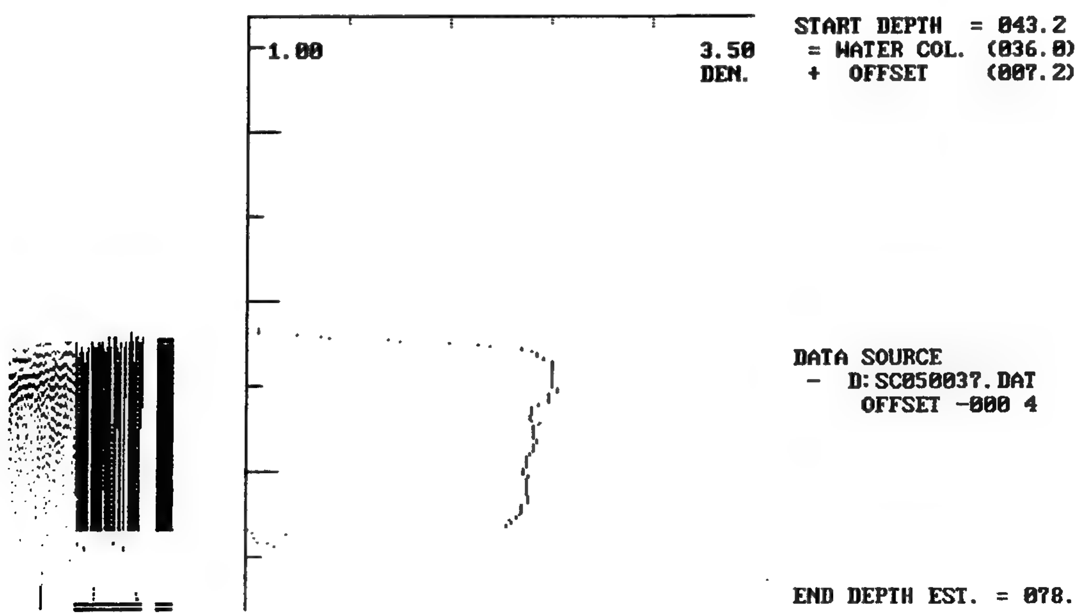
- D: SC050029.DAT
OFFSET -000 4
END DEPTH EST. = 113.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START DEPTH = 043.2
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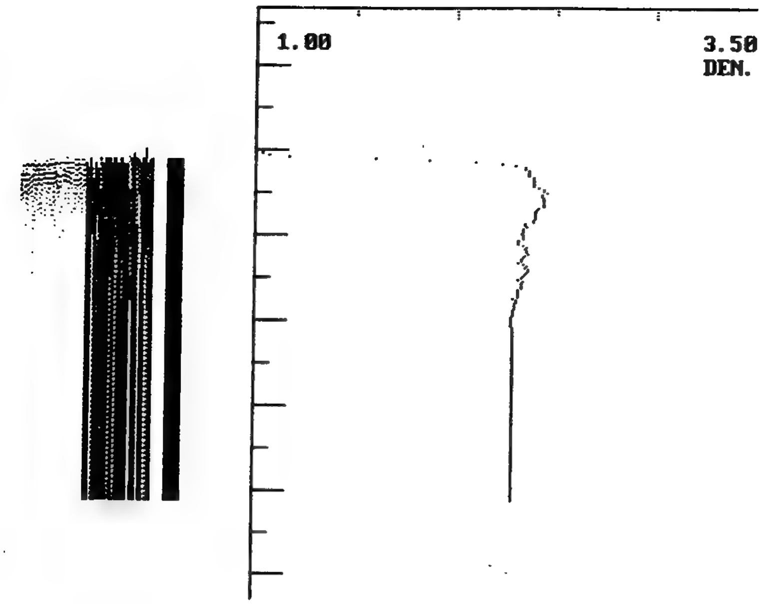
END DEPTH EST. = 078.



START DEPTH = 043.2
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+ OFFSET (007.2)

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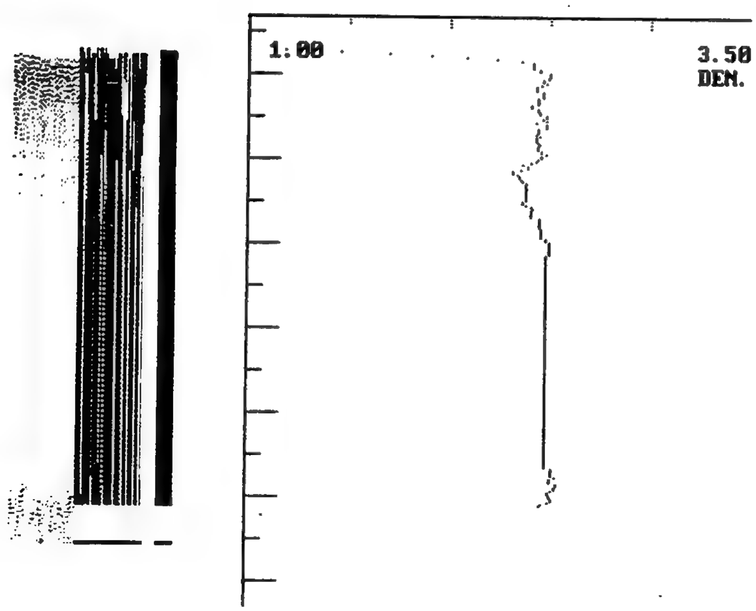
END DEPTH EST. = 113.



START DEPTH = 043.2
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- D: SC050051.DAT
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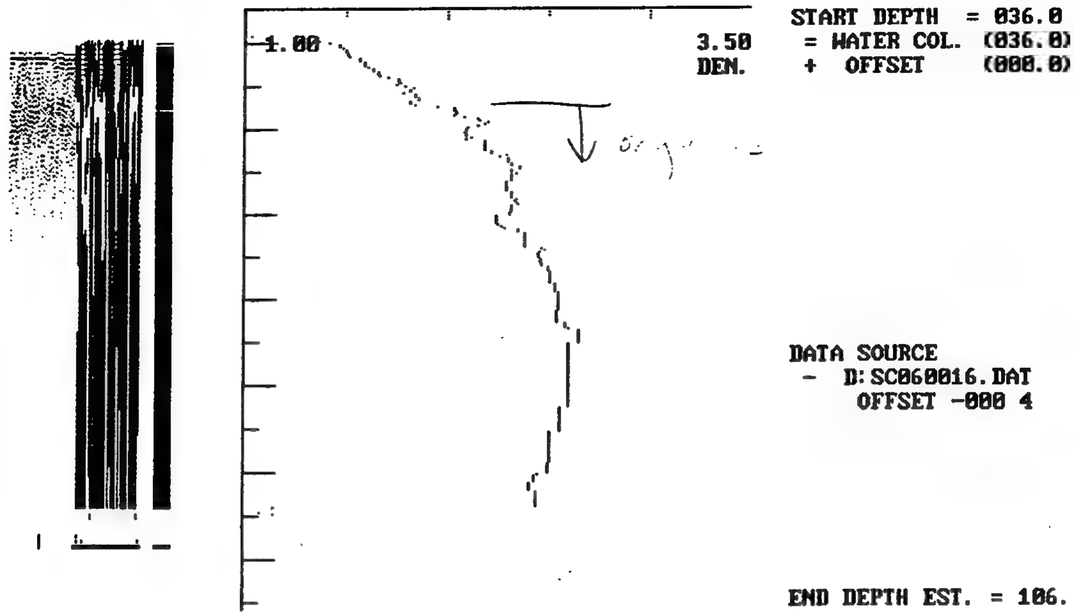
END DEPTH EST. = 113.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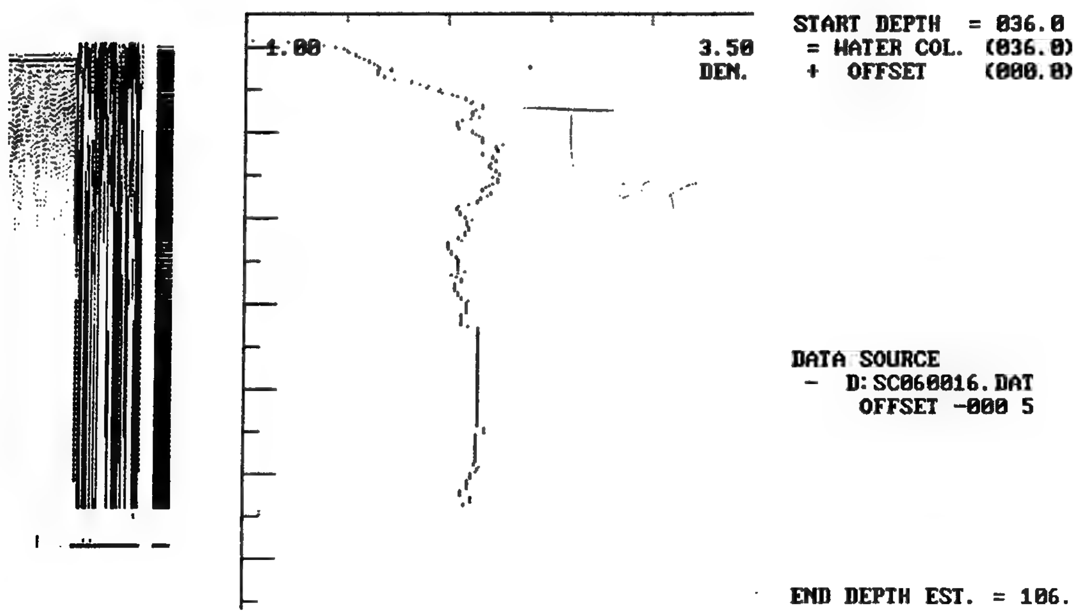
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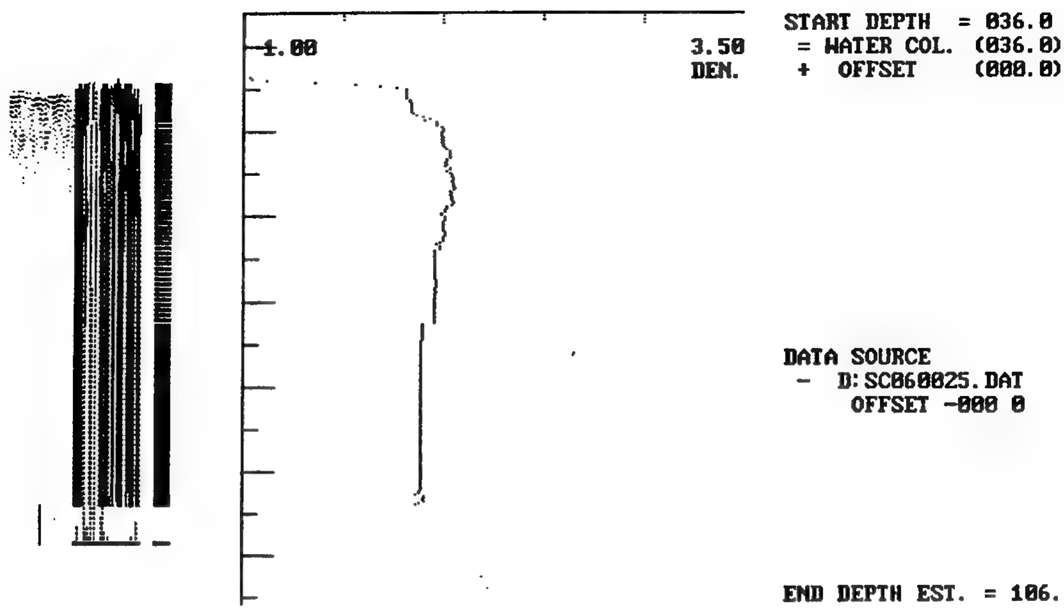
OFFSET -000 5
END DEPTH EST. = 106.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START DEPTH = 036.0
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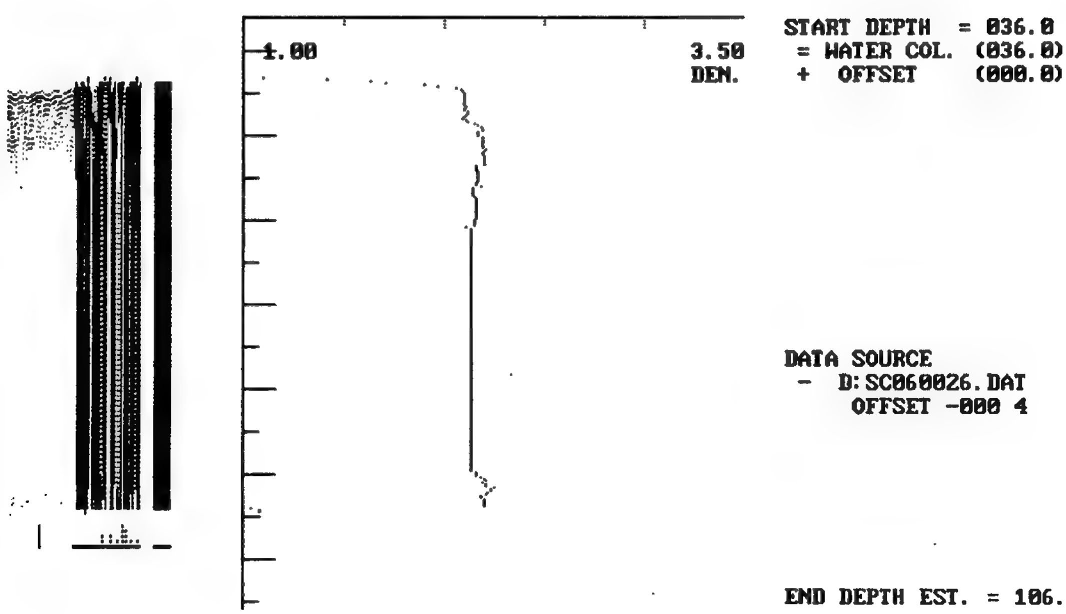
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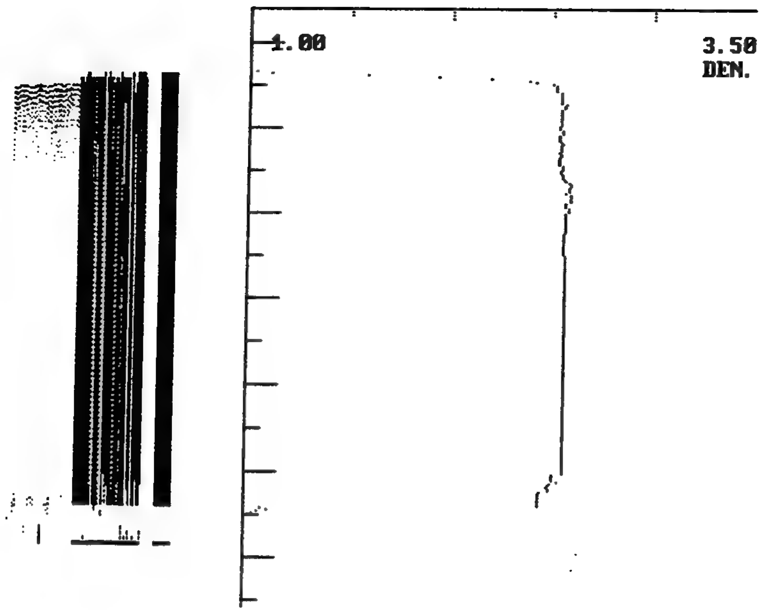
END DEPTH EST. = 106.



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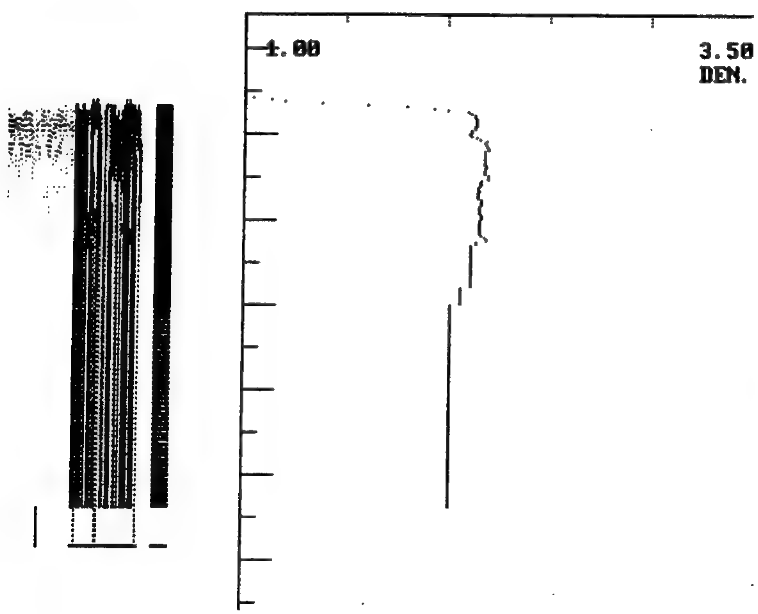

START DEPTH = 036.0
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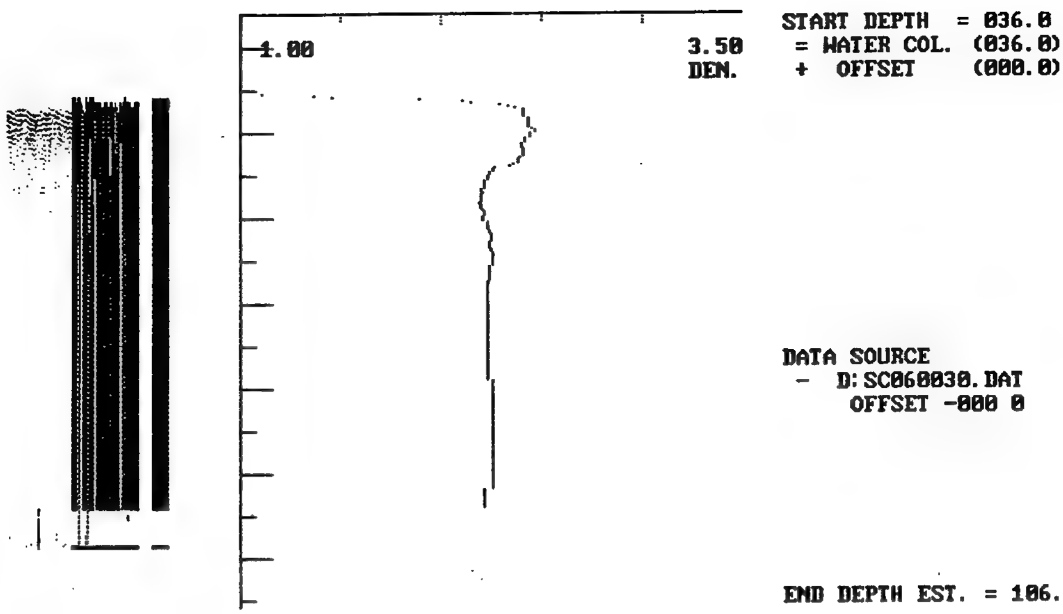
END DEPTH EST. = 106.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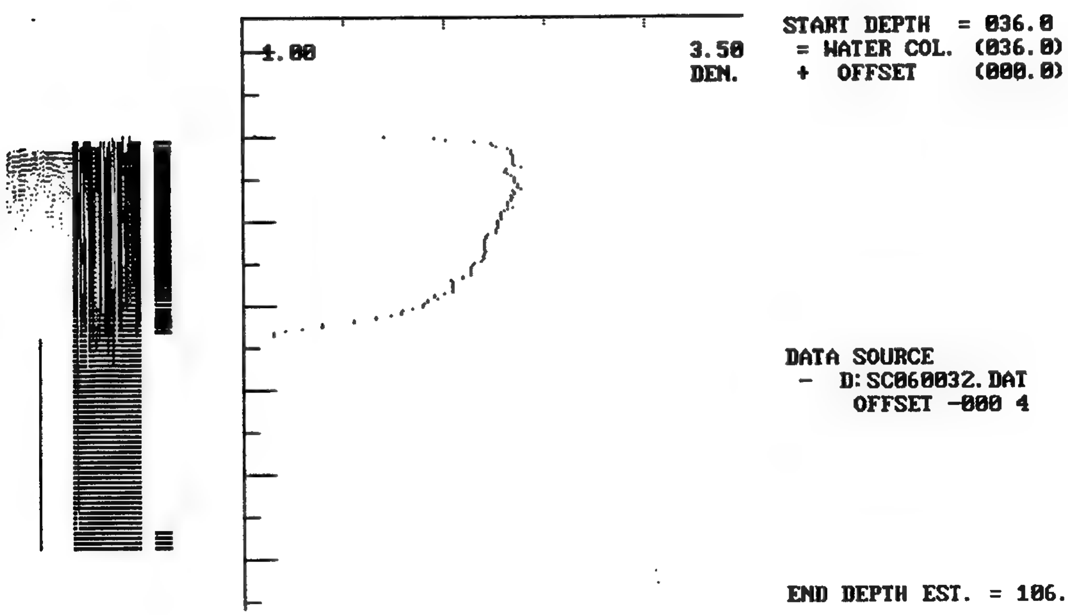
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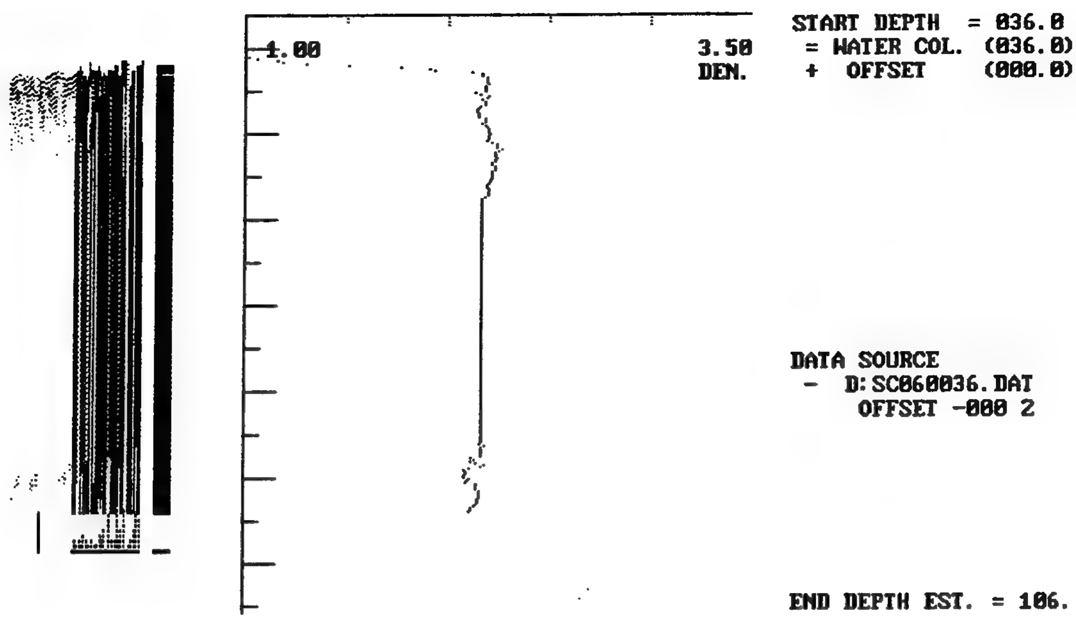
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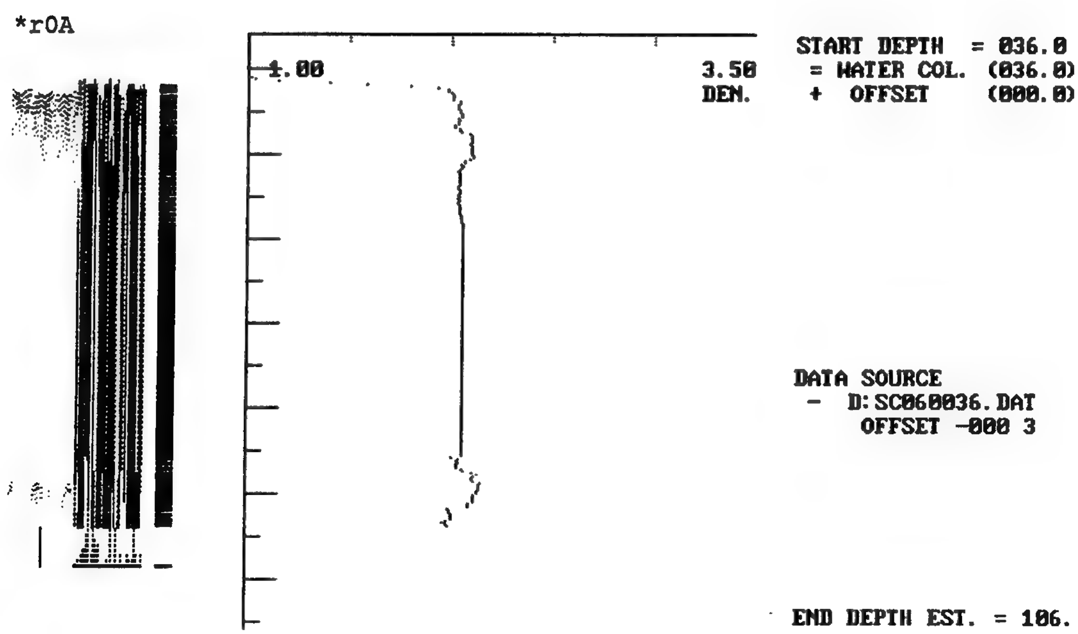
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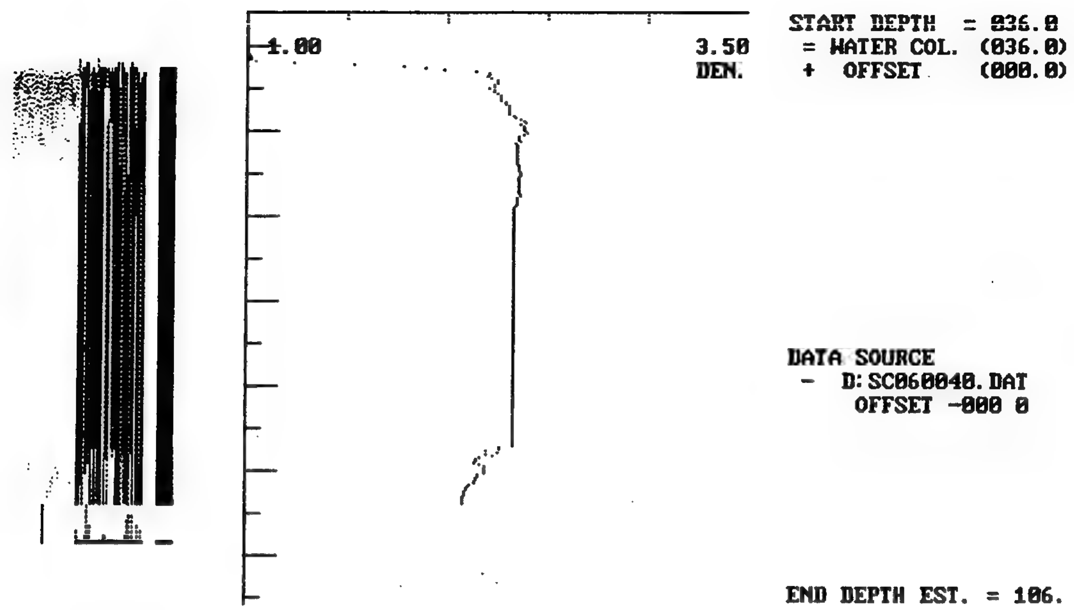
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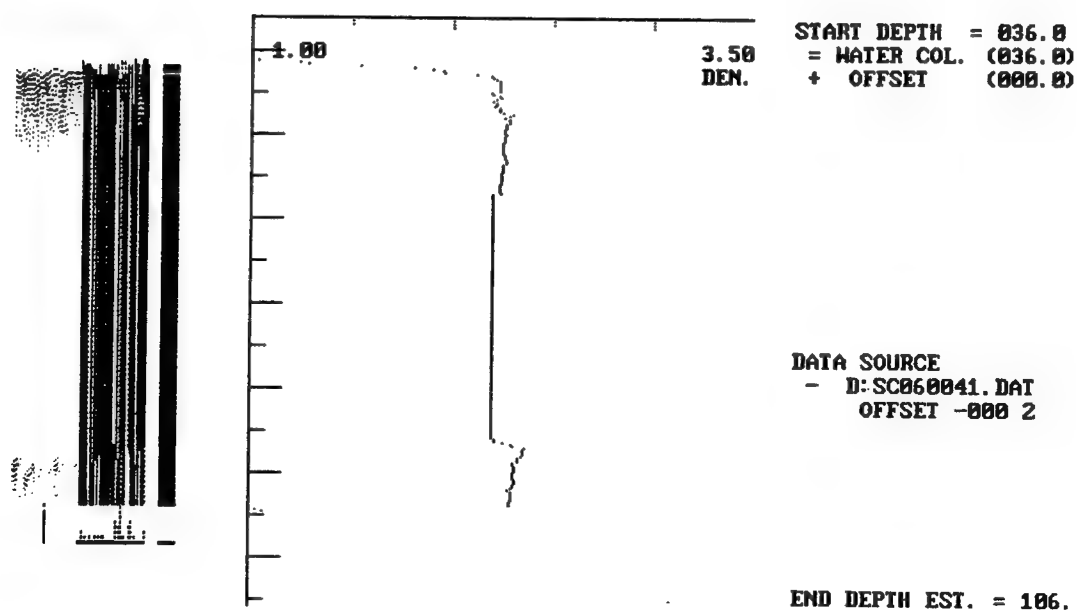
END DEPTH EST. = 106.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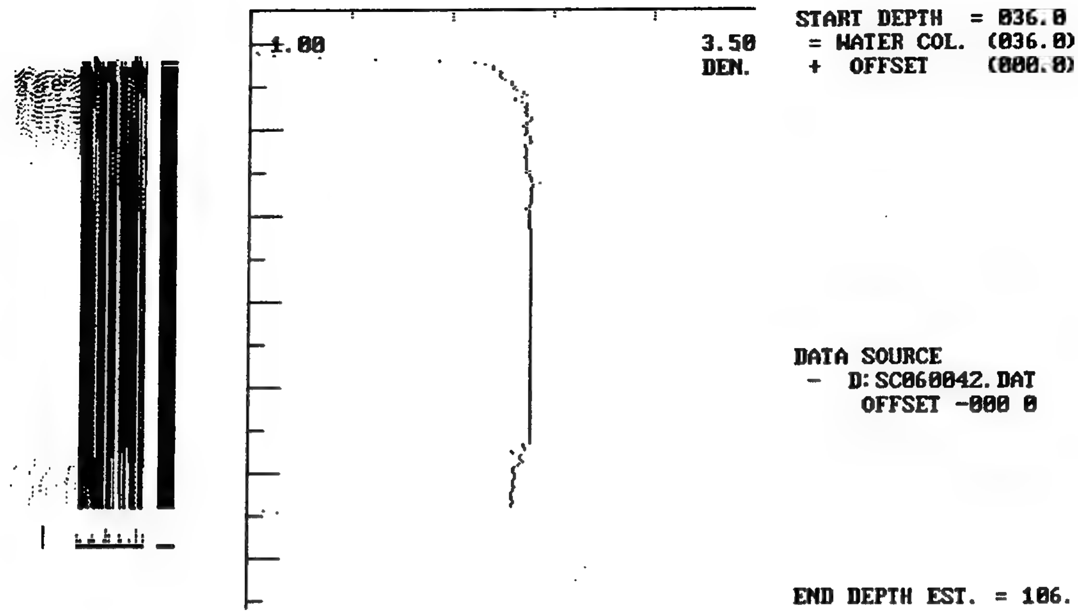
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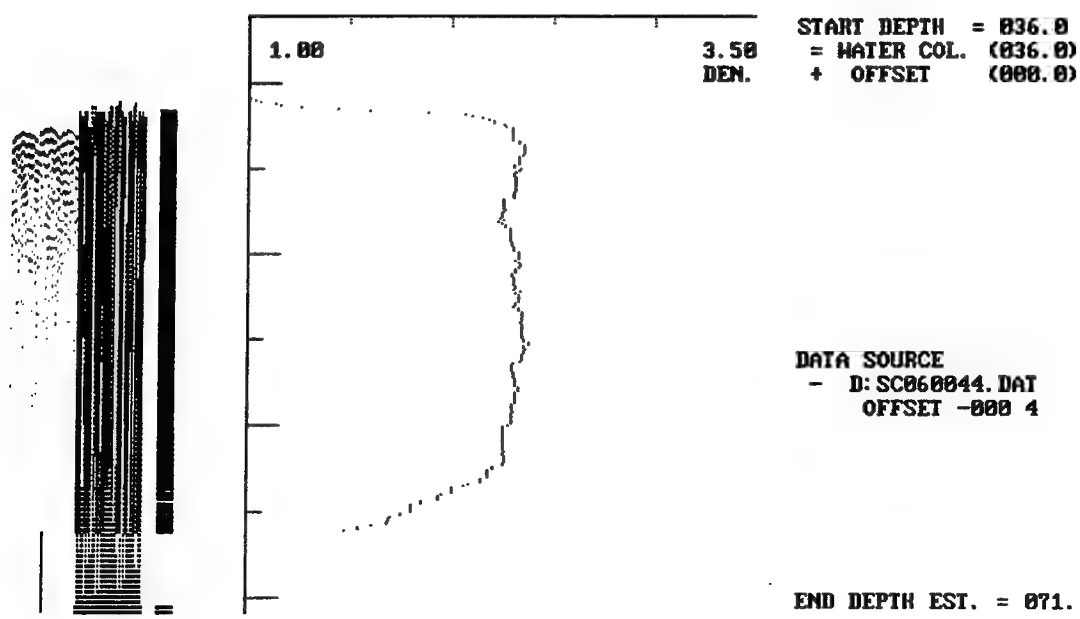
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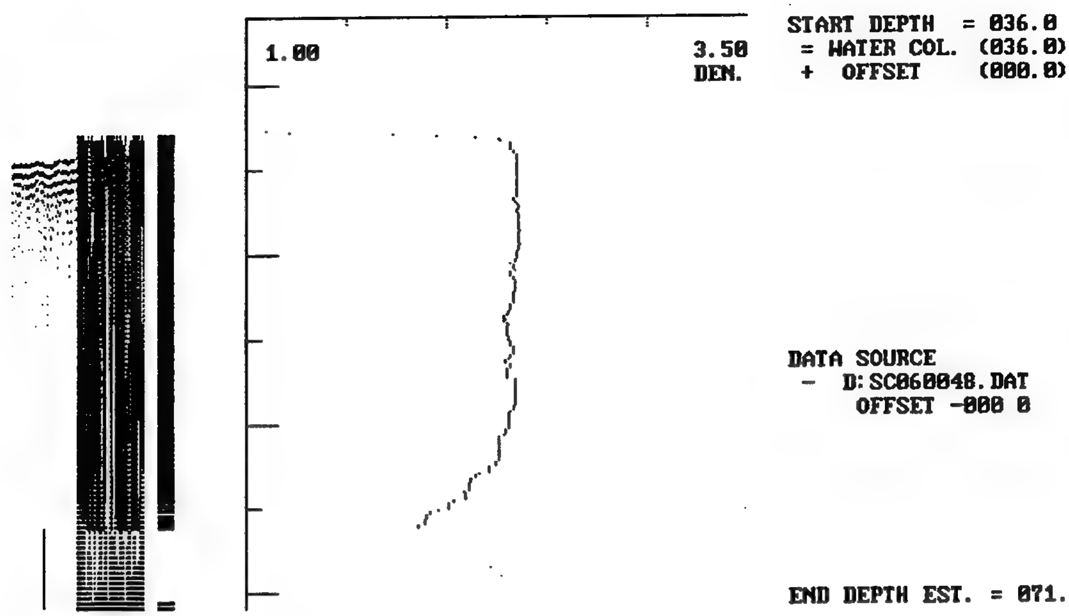
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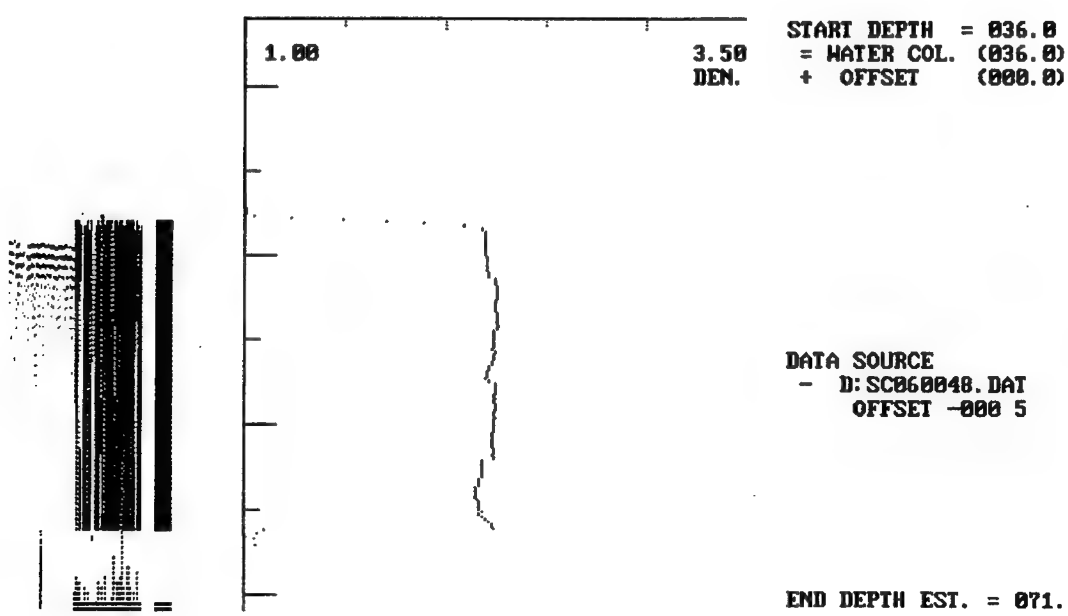
END DEPTH EST. = 071.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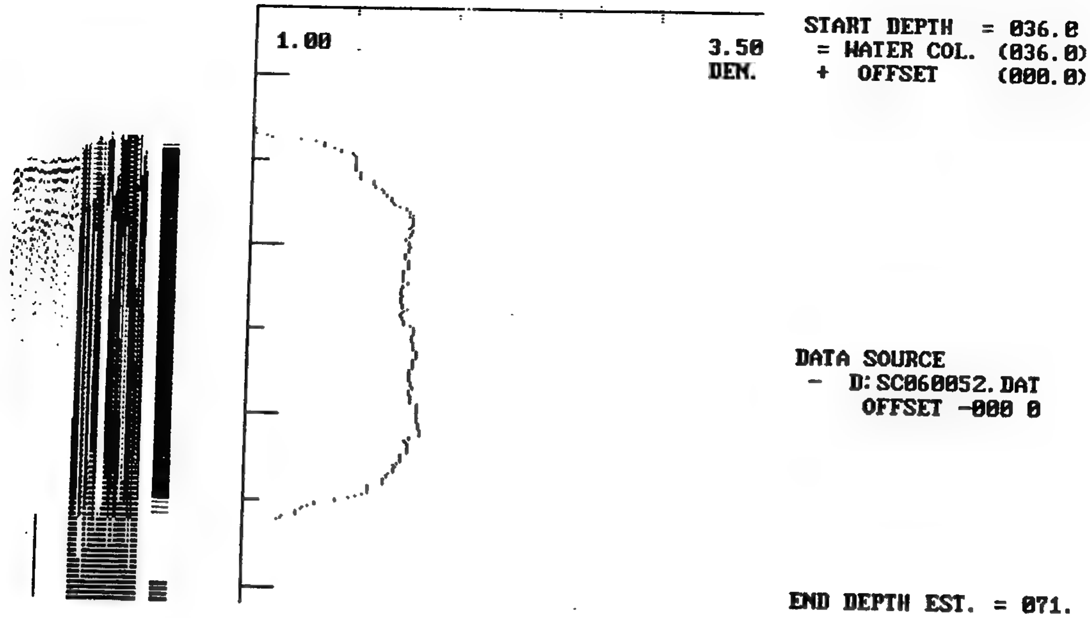
END DEPTH EST. = 071.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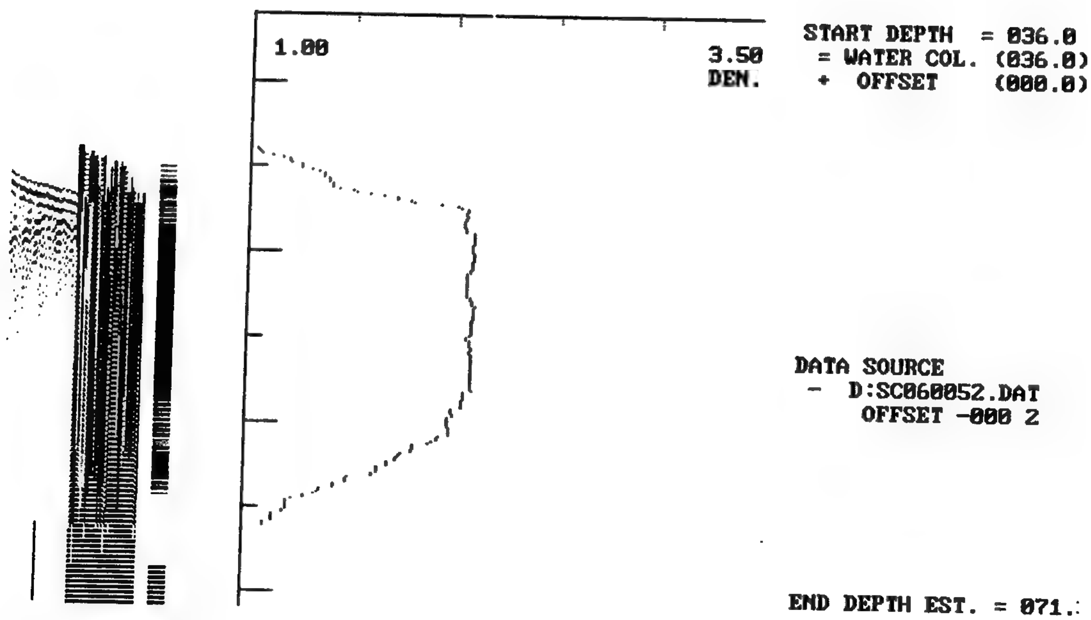
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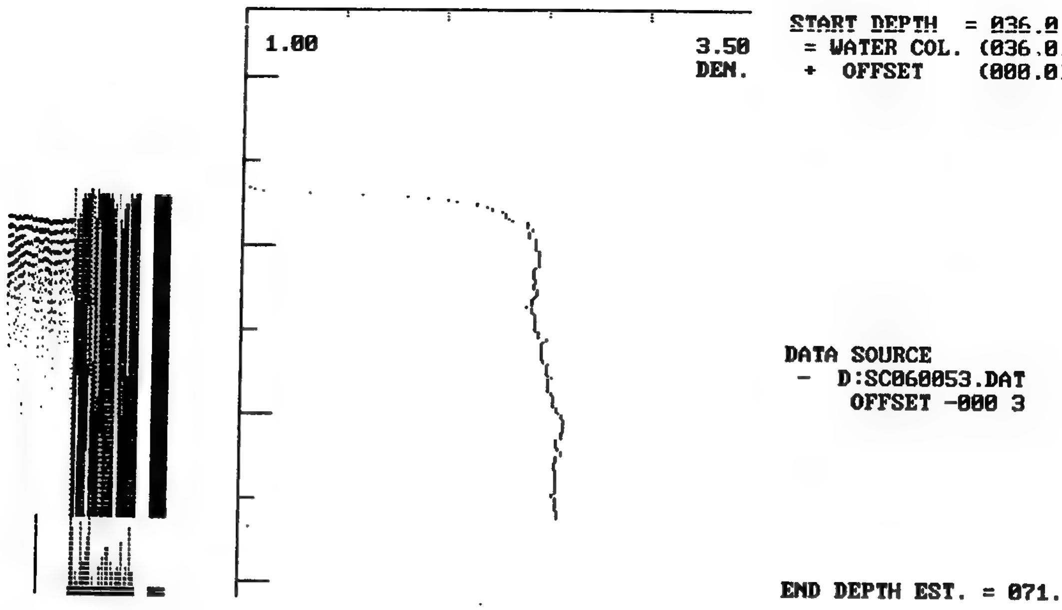
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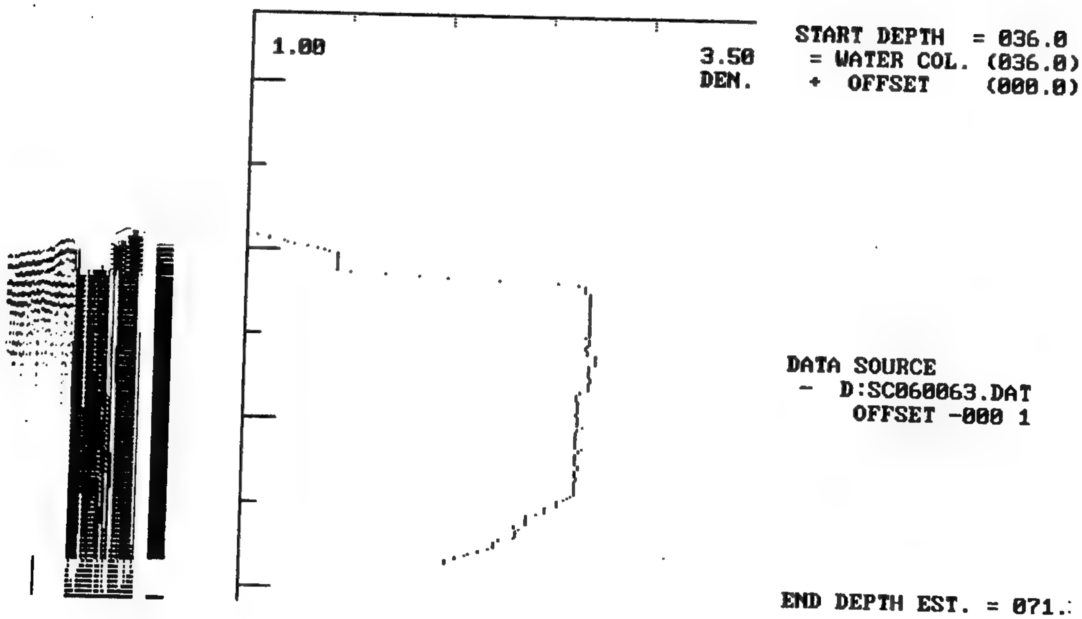
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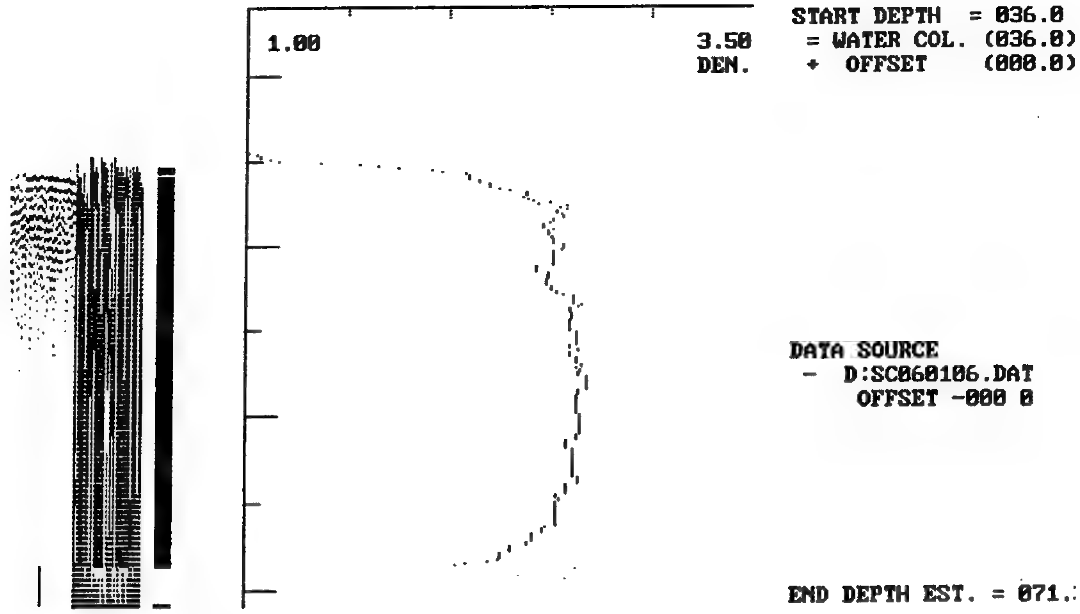
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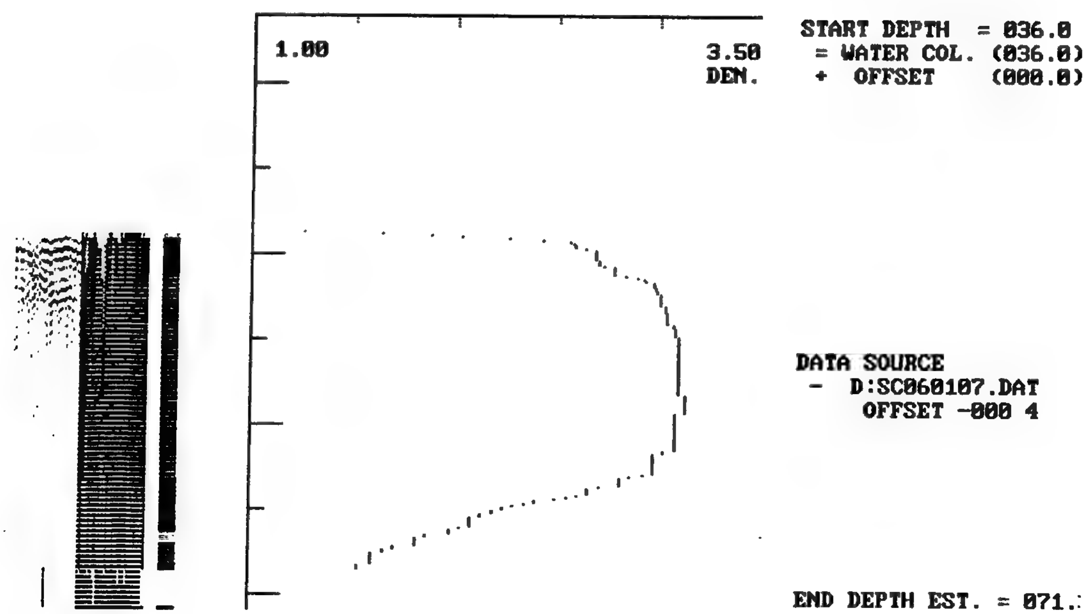
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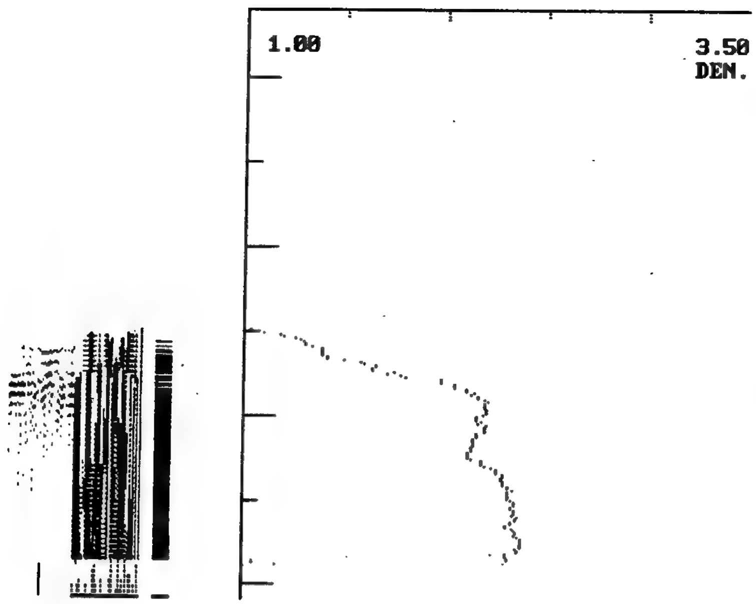
END DEPTH EST. = 071.:



START DEPTH = 036.0
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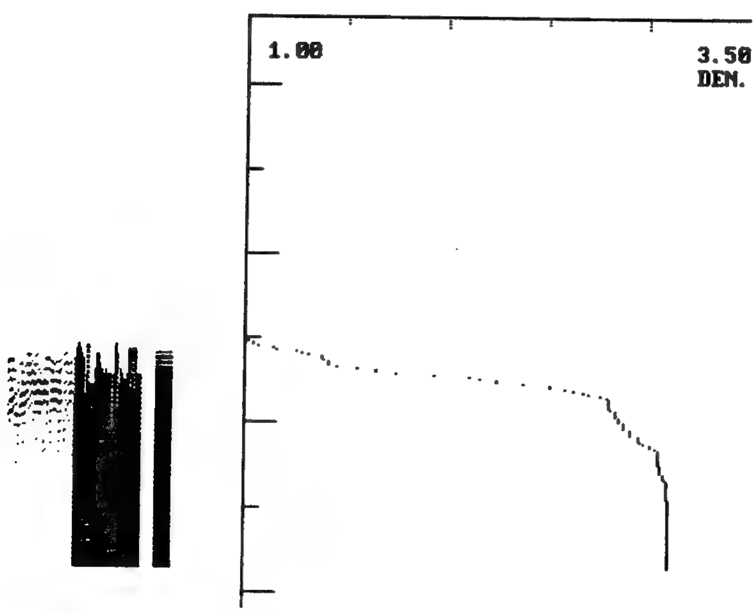
END DEPTH EST. = 071.:



START DEPTH = 036.0
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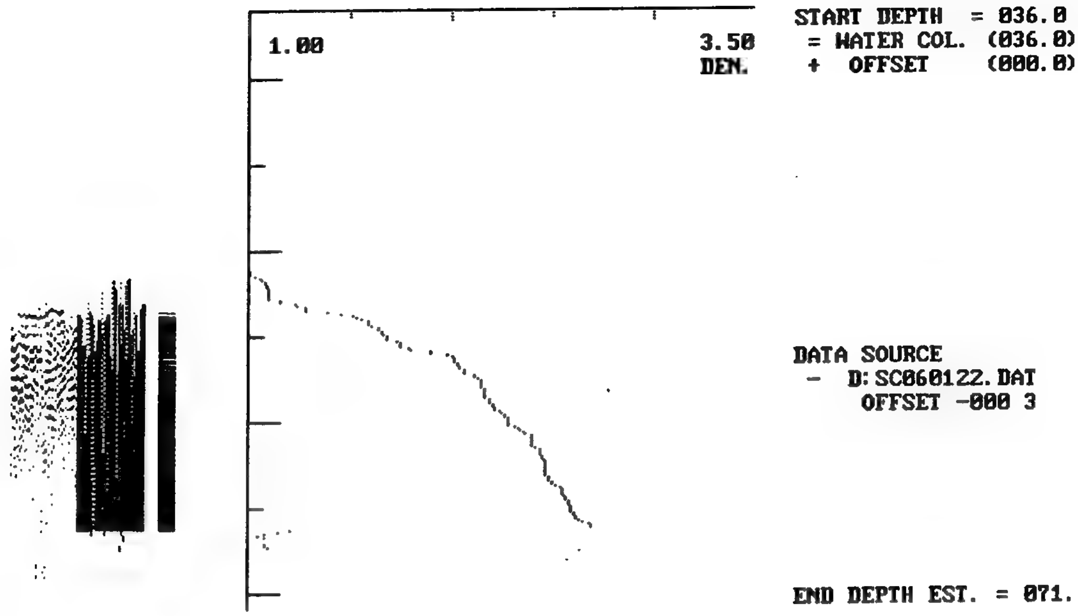
END DEPTH EST. = 071.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START DEPTH = 036.0
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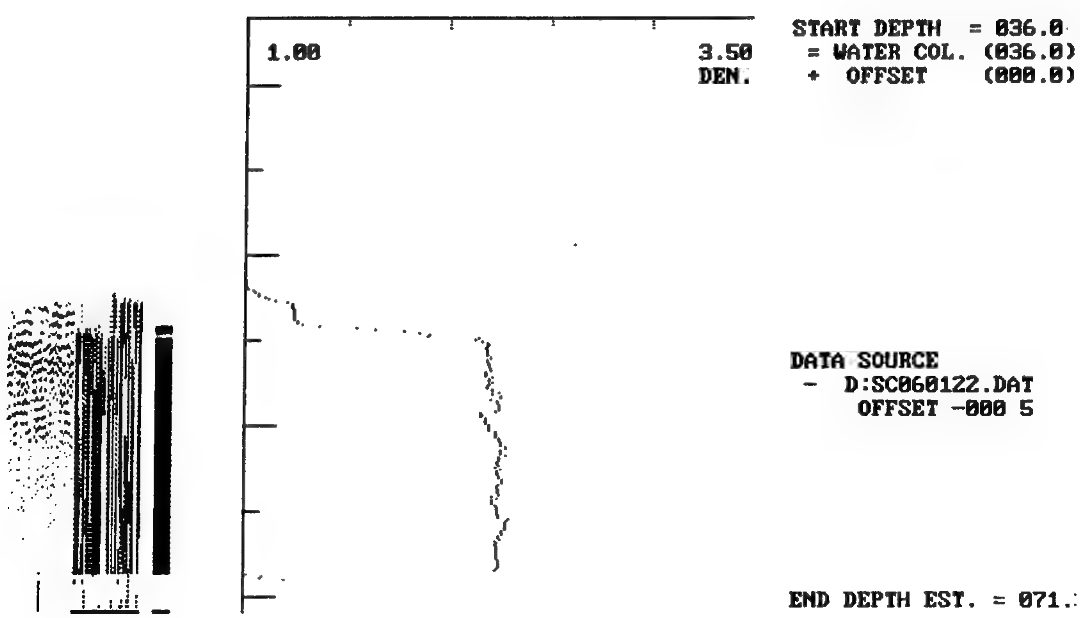
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START DEPTH = 036.0
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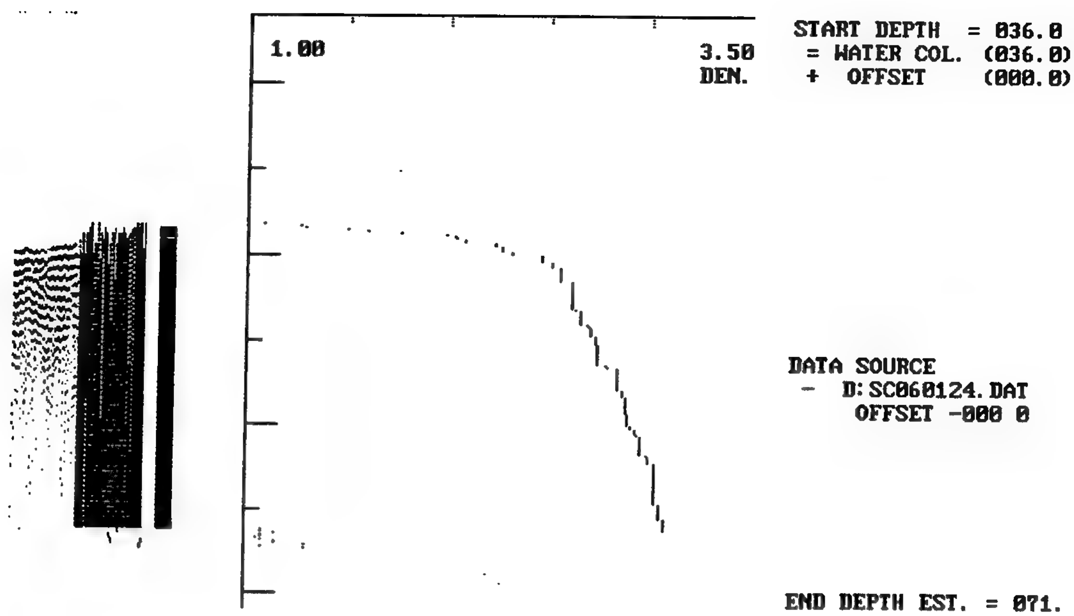
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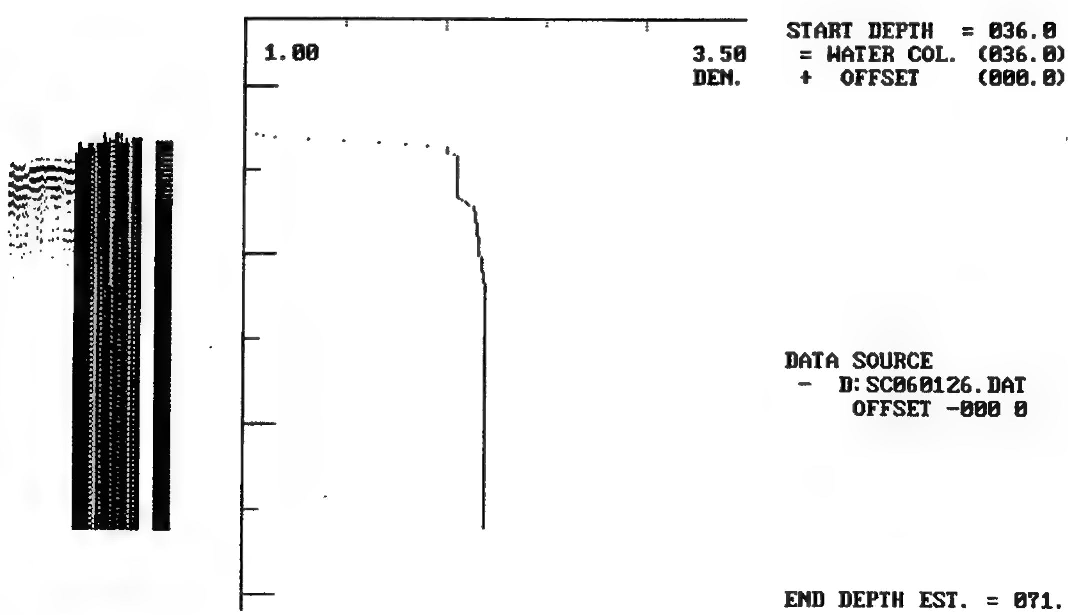
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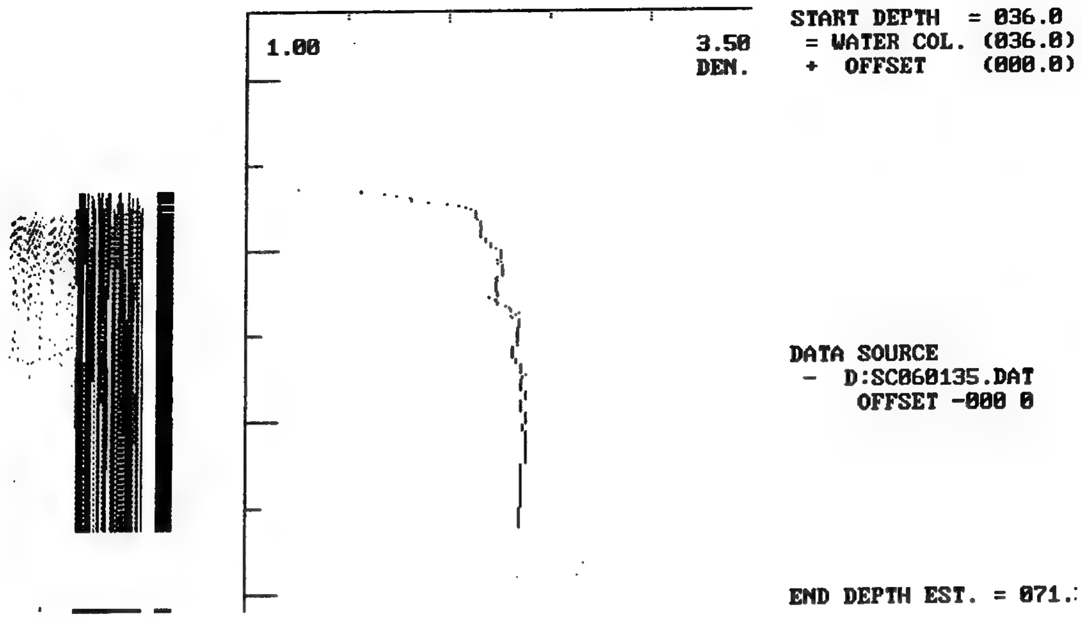
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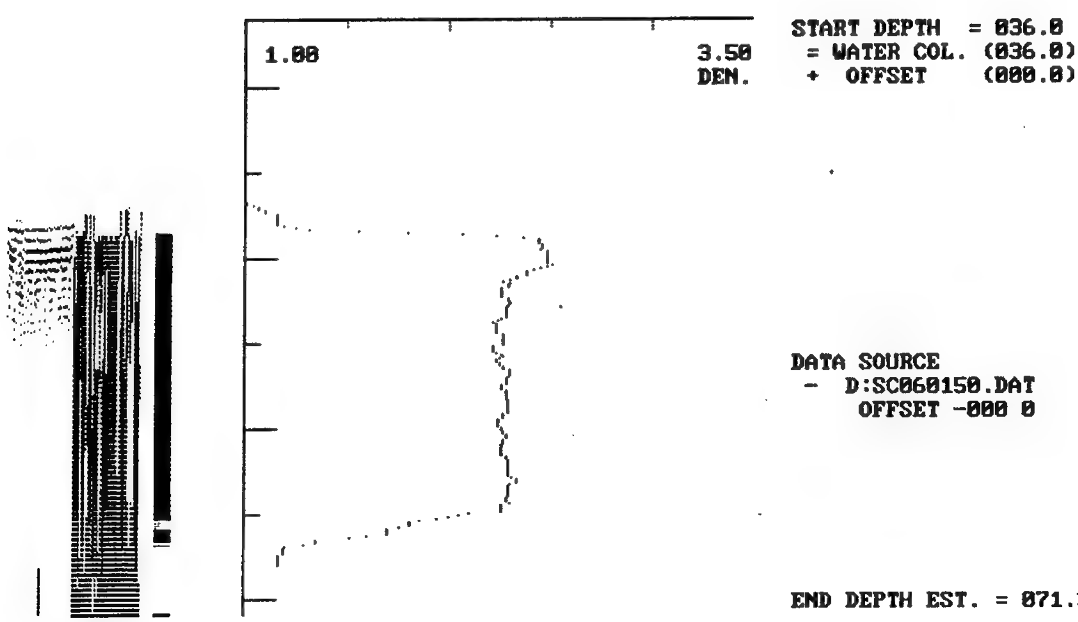
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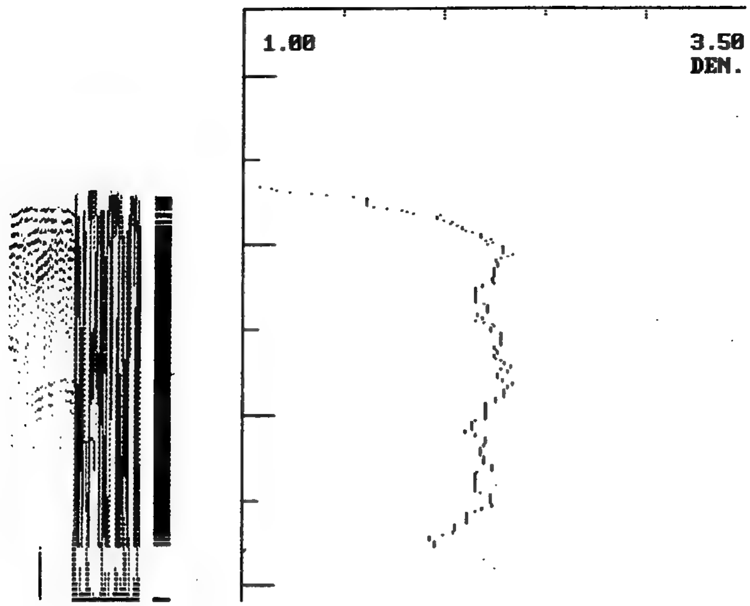

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= WATER COL. (036.0)
+ OFFSET (000.0)

DATA SOURCE
- D:SC060153.DAT
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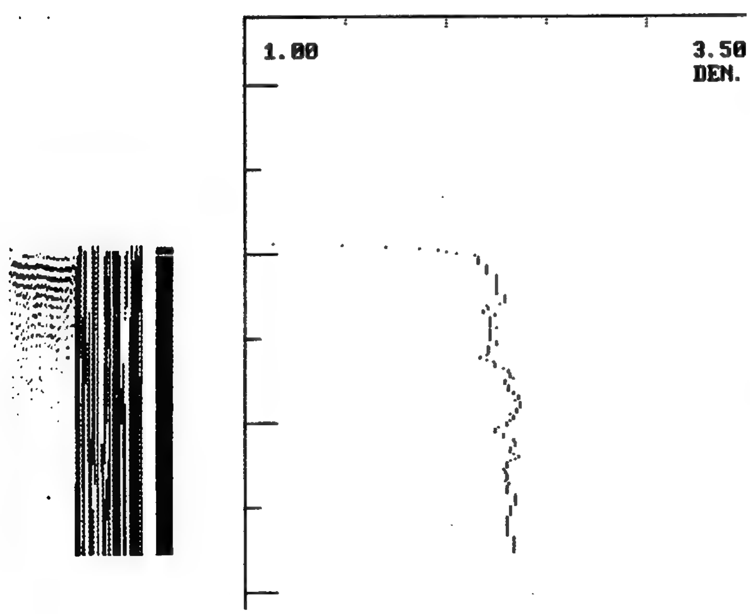
END DEPTH EST. = 071.:



START DEPTH = 036.0
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+ OFFSET (000.0)

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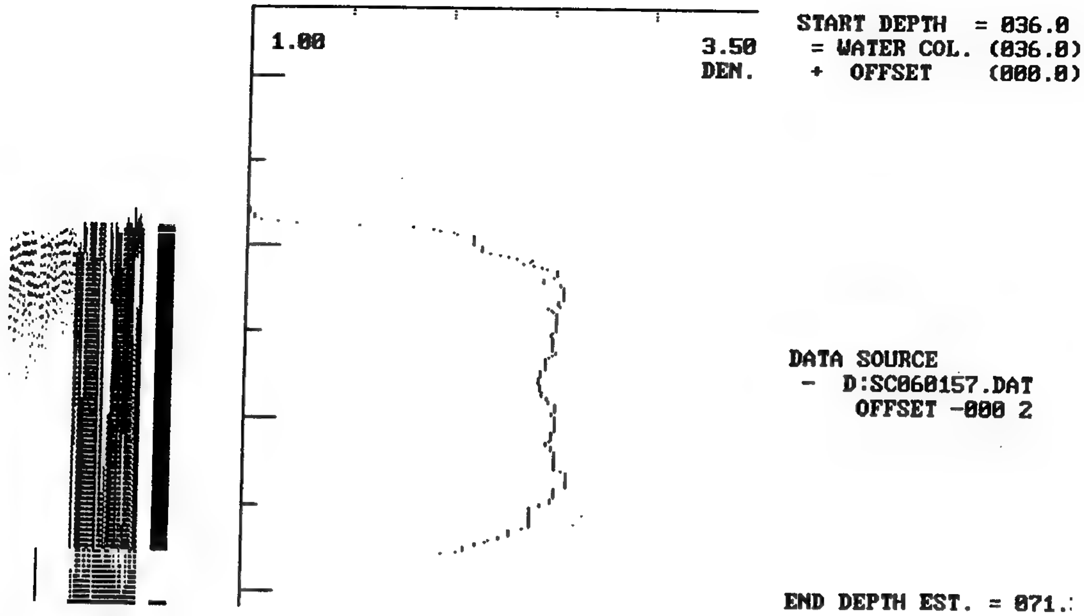
END DEPTH EST. = 071.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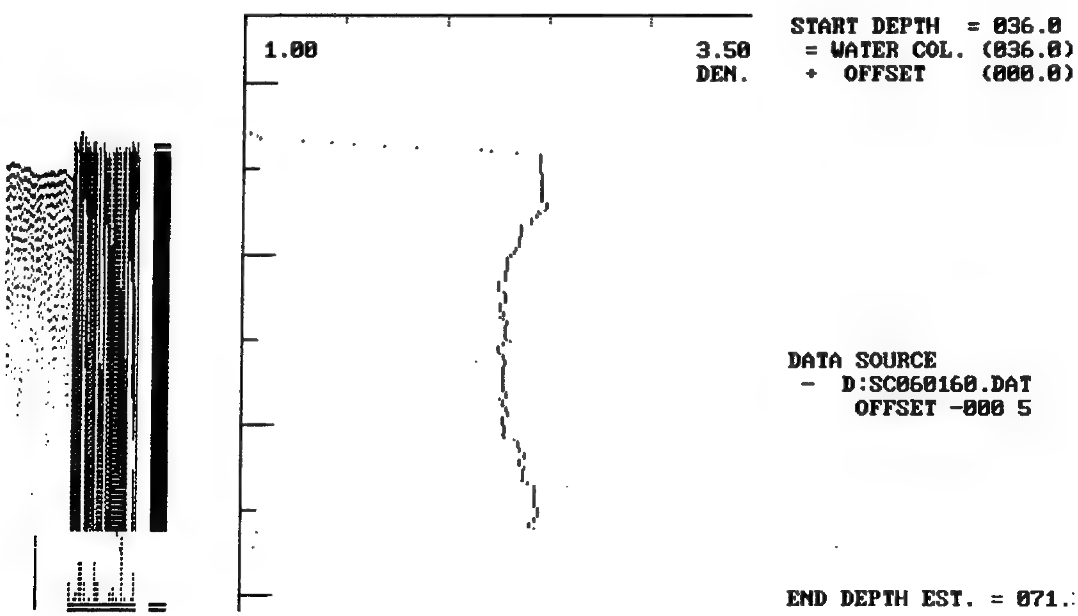
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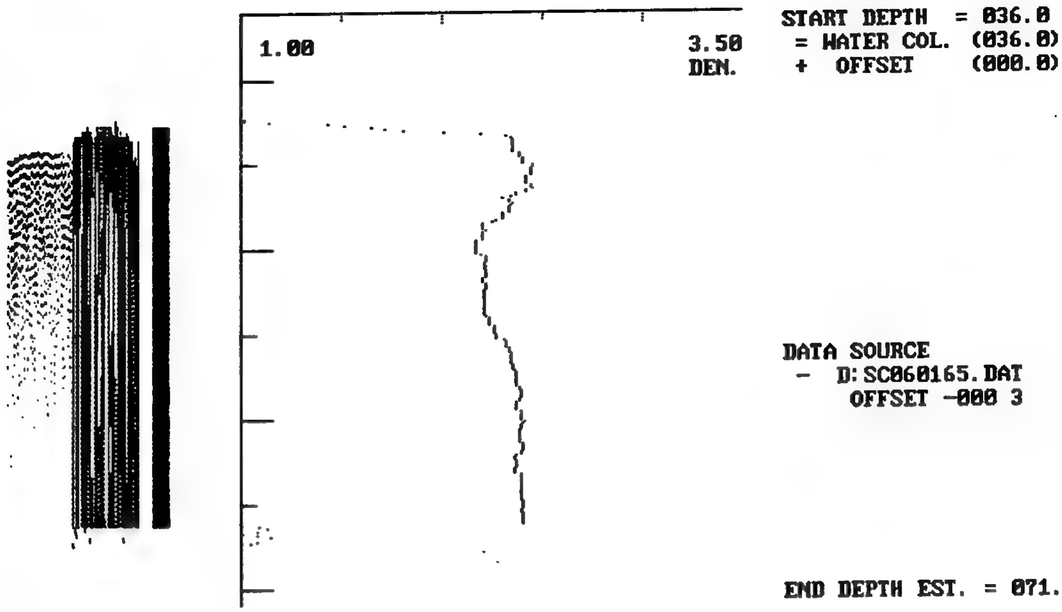
END DEPTH EST. = 071.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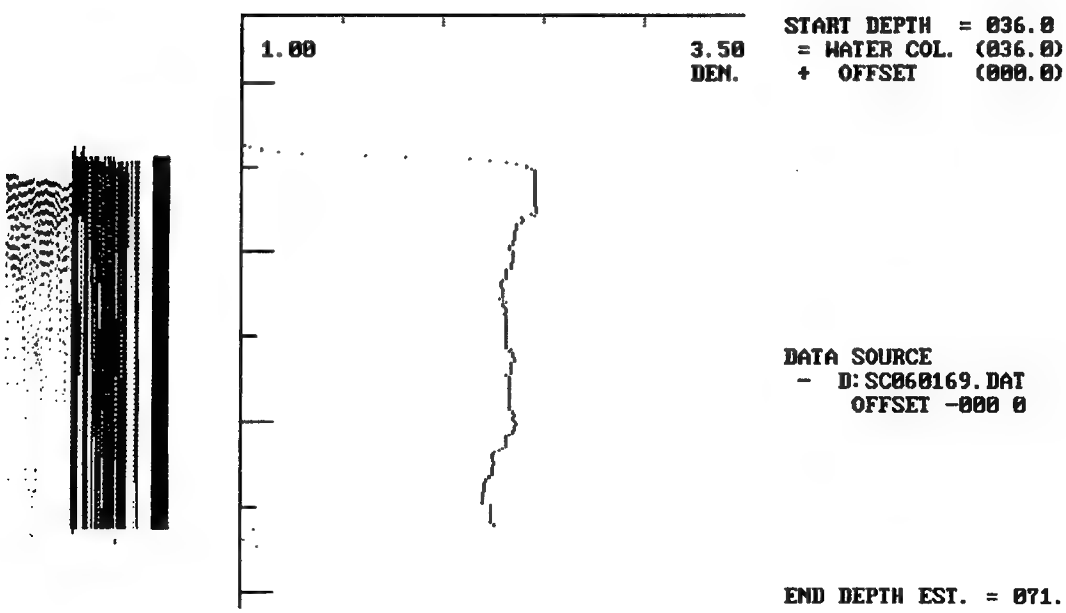
- D:SC060165.DAT
OFFSET -000 3
END DEPTH EST. = 071.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START DEPTH = 036.0
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- D:SC060169.DAT
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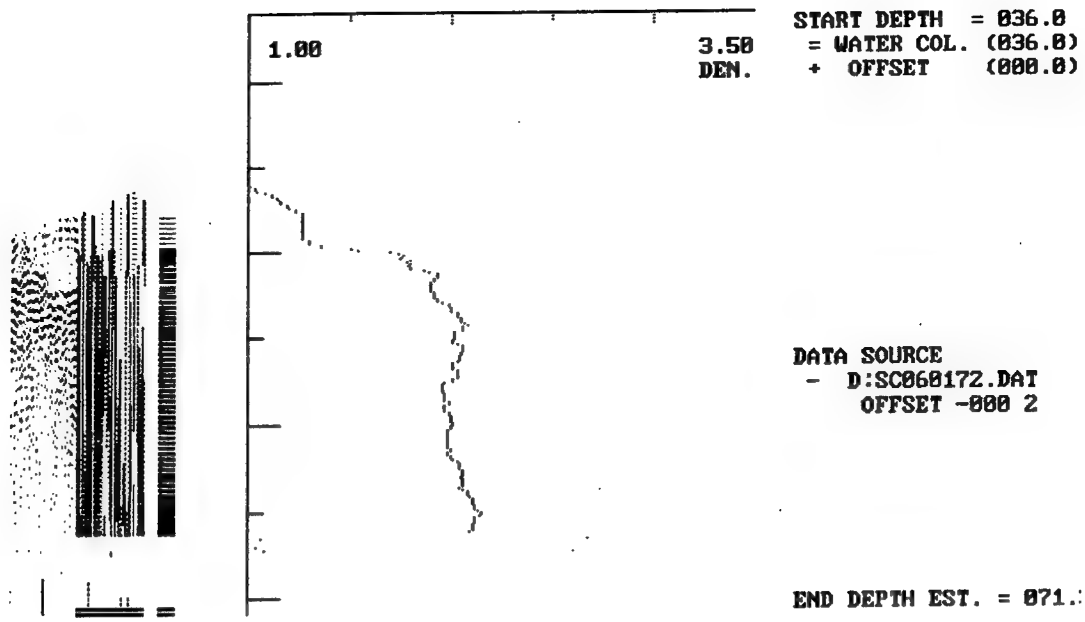
END DEPTH EST. = 071.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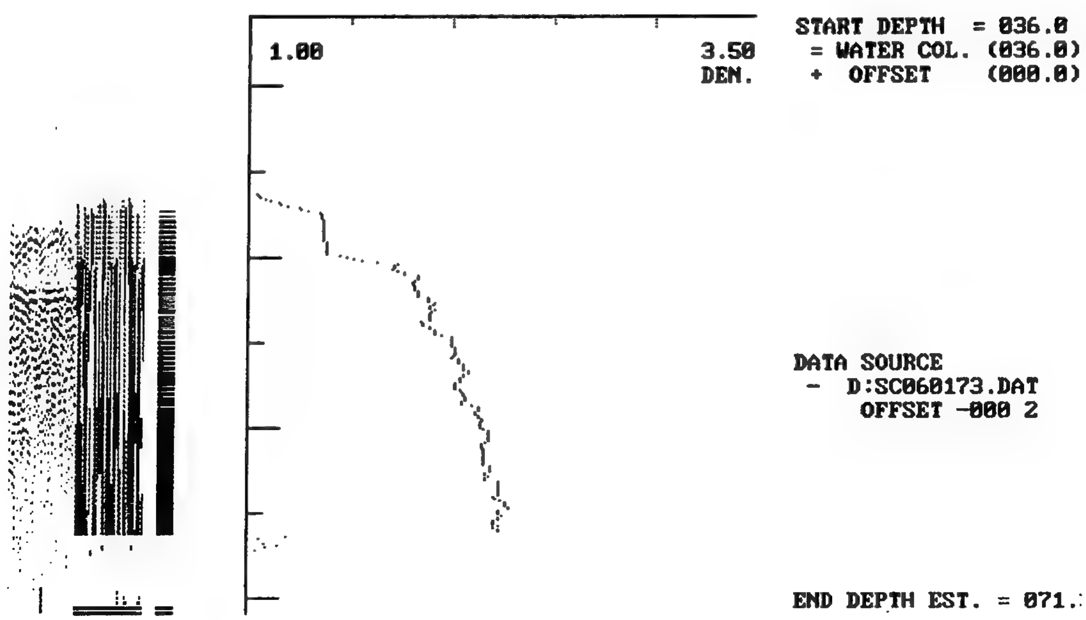
END DEPTH EST. = 071.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START DEPTH = 036.0
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- D:SC060173.DAT
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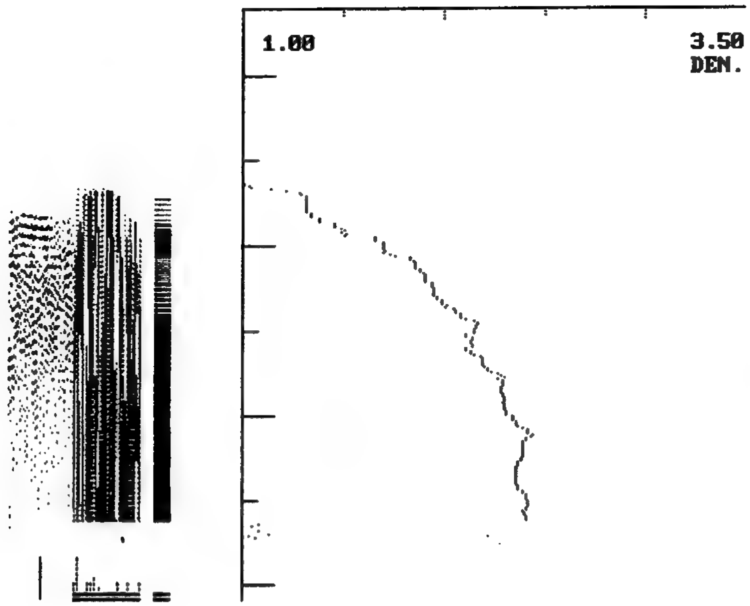
END DEPTH EST. = 071.



START DEPTH = 036.0
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+ OFFSET (000.0)

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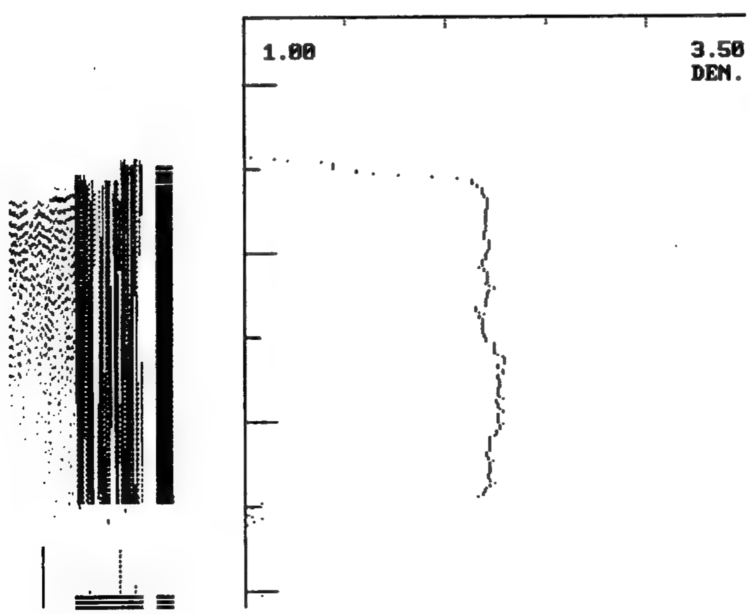
END DEPTH EST. = 071.:



START DEPTH = 036.0
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+ OFFSET (000.0)

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- d:sc060177.DAT
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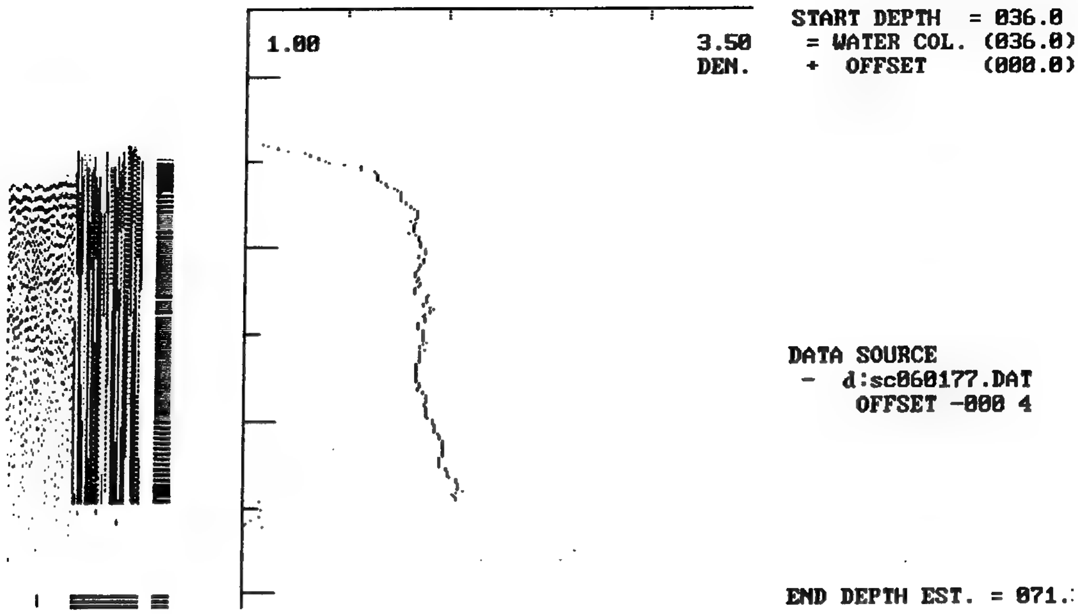
END DEPTH EST. = 071.: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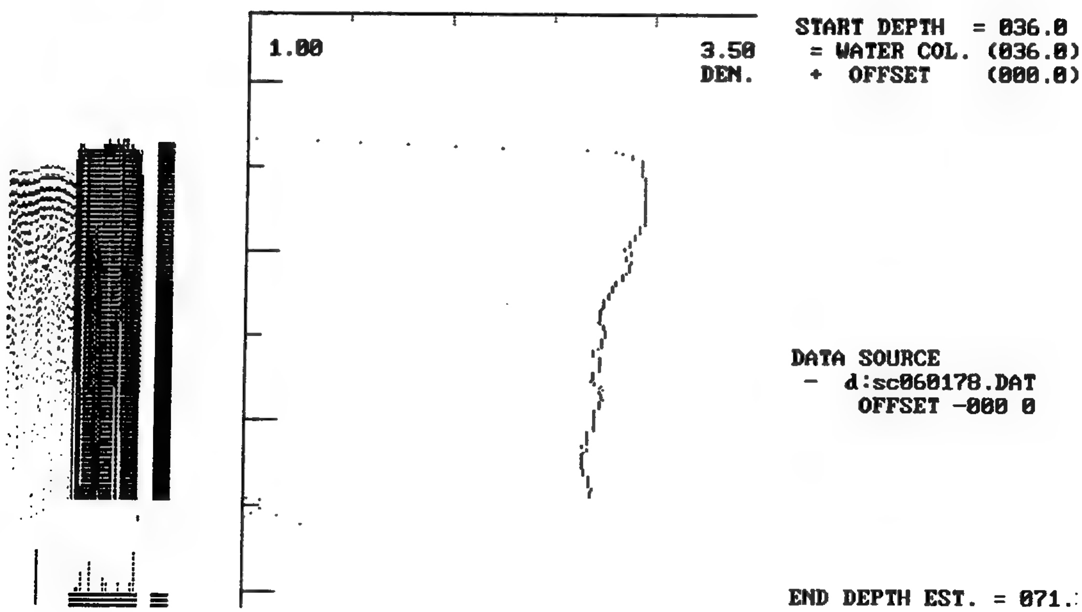
END DEPTH EST. = 071.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+ OFFSET (000.0)
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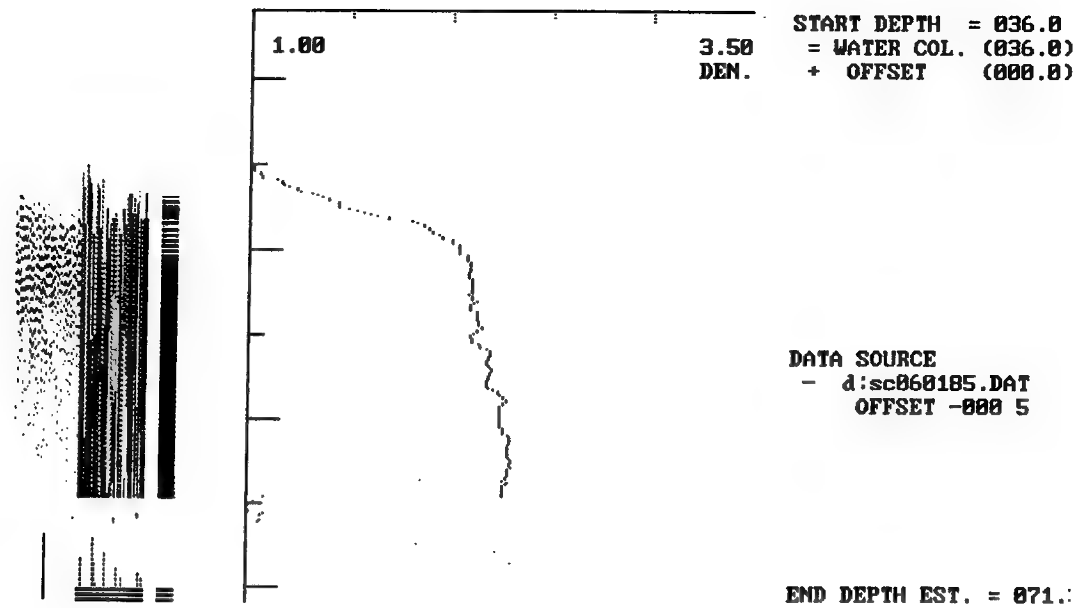
- d:sc060178.DAT
OFFSET -000 0
END DEPTH EST. = 071.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START DEPTH = 036.0
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+ OFFSET (000.0)
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- d:sc060185.DAT
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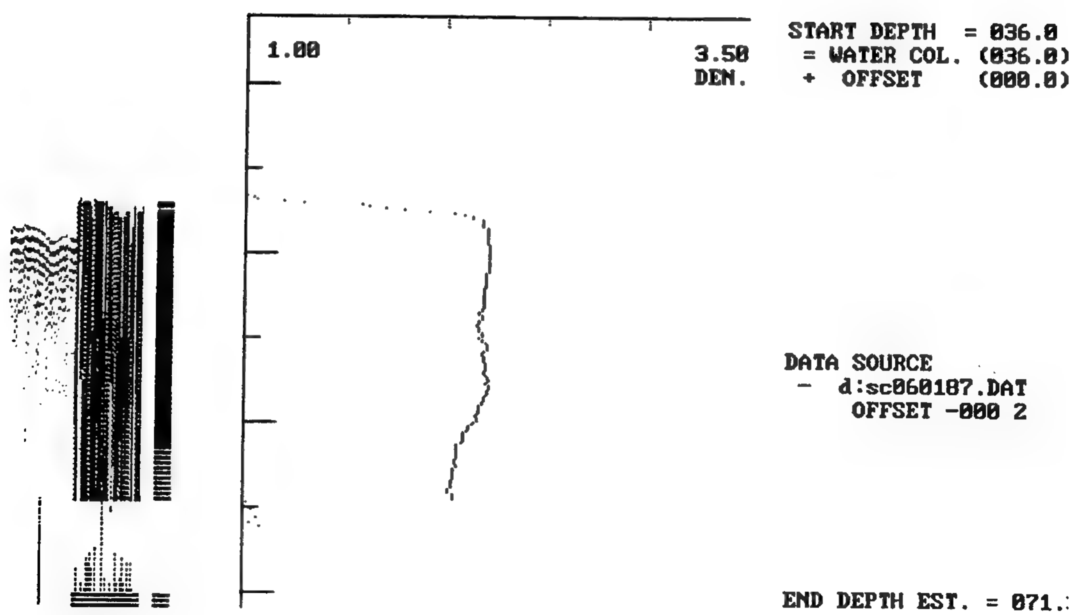
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START DEPTH = 036.0
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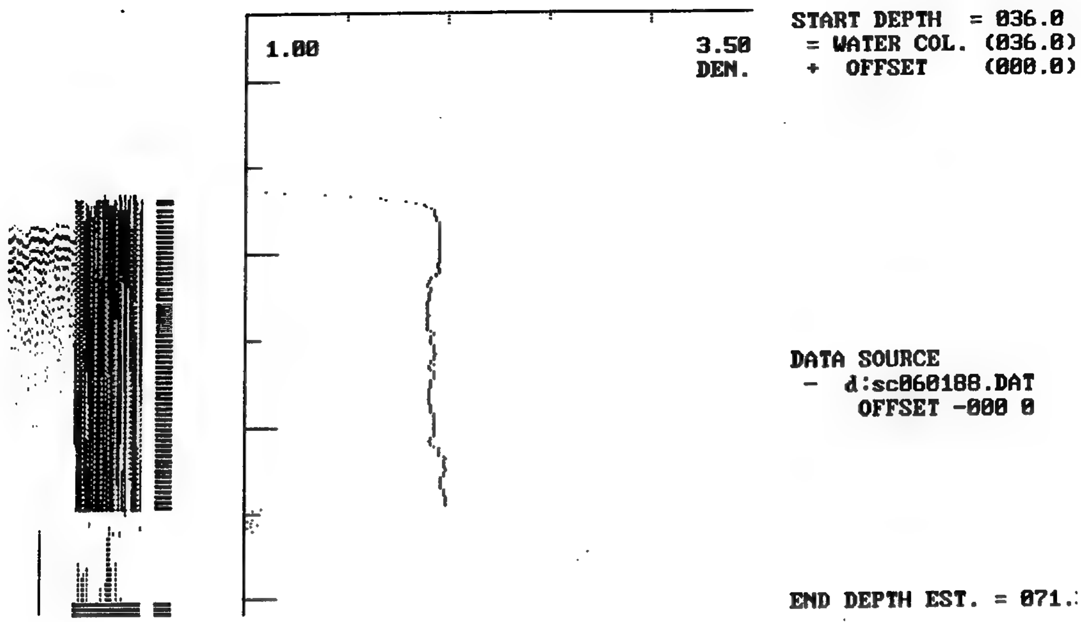
+ OFFSET (000.0)
DATA SOURCE
- d:sc060187.DAT
OFFSET -000 2
END DEPTH EST. = 071.: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START DEPTH = 036.0
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+ OFFSET (000.0)
DATA SOURCE
- d:sc060188.DAT
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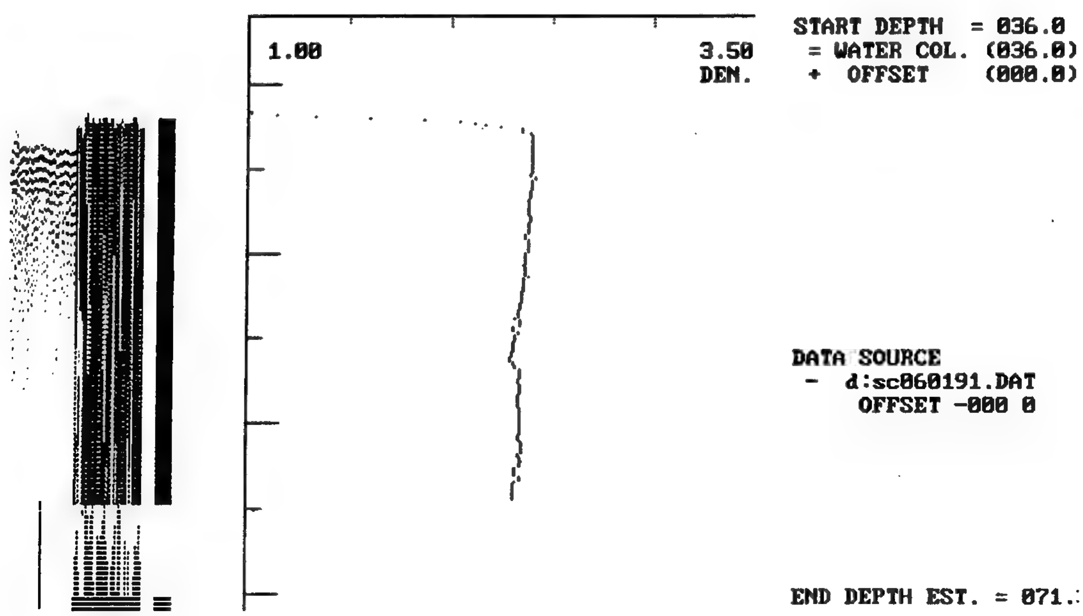
END DEPTH EST. = 071.: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START DEPTH = 036.0
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+ OFFSET (000.0)
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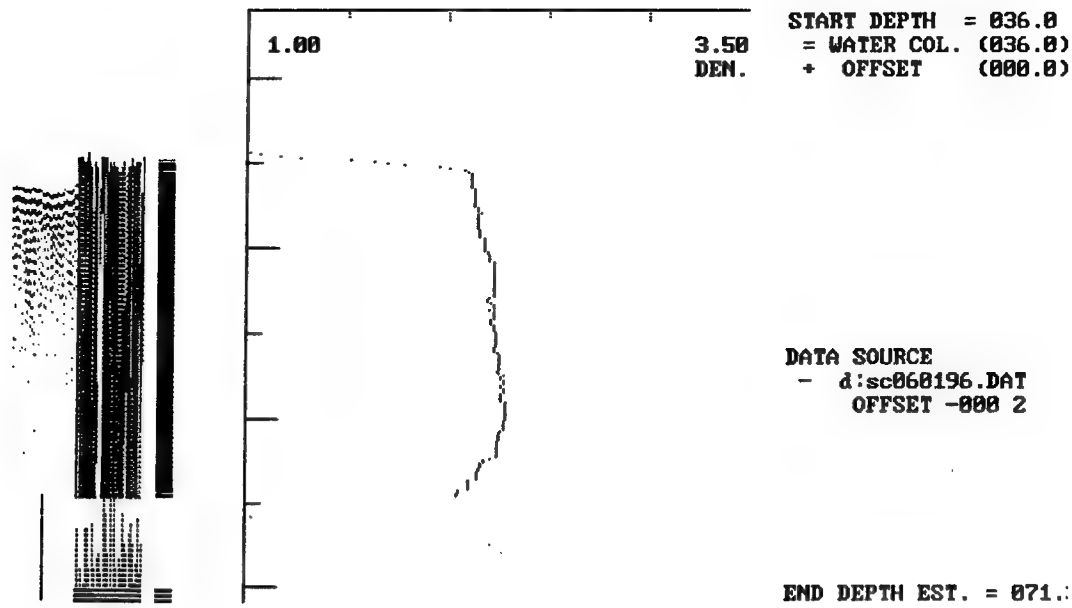
END DEPTH EST. = 071.:


START DEPTH = 036.0
= WATER COL. (036.0)
+ OFFSET (000.0)
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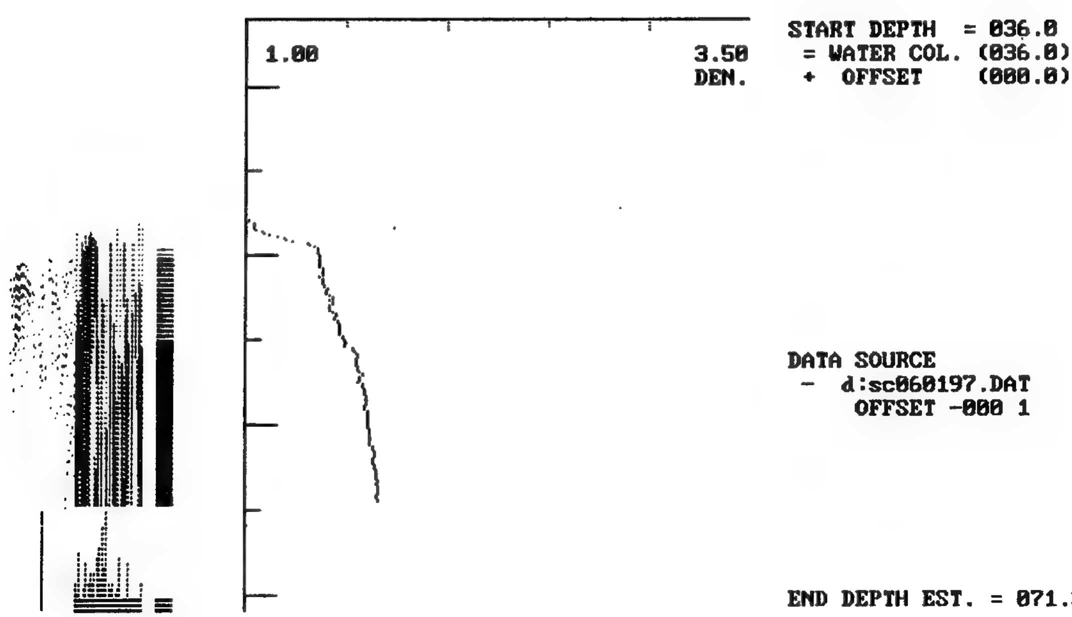
- d:sc060196.DAT
OFFSET -000 2
END DEPTH EST. = 071.:


START DEPTH = 036.0
= WATER COL. (036.0)
+ OFFSET (000.0)
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DEN.
DATA SOURCE
- d:sc060197.DAT
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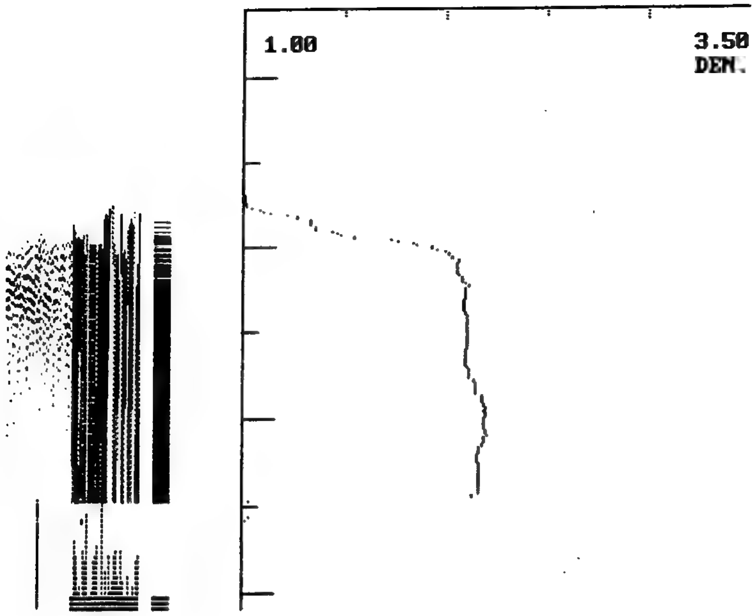
END DEPTH EST. = 071.:



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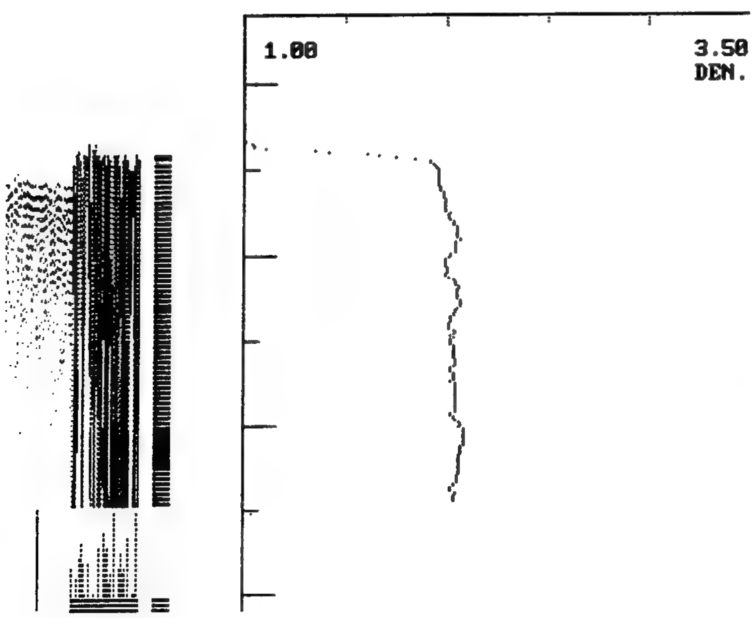
END DEPTH EST. = 071.:



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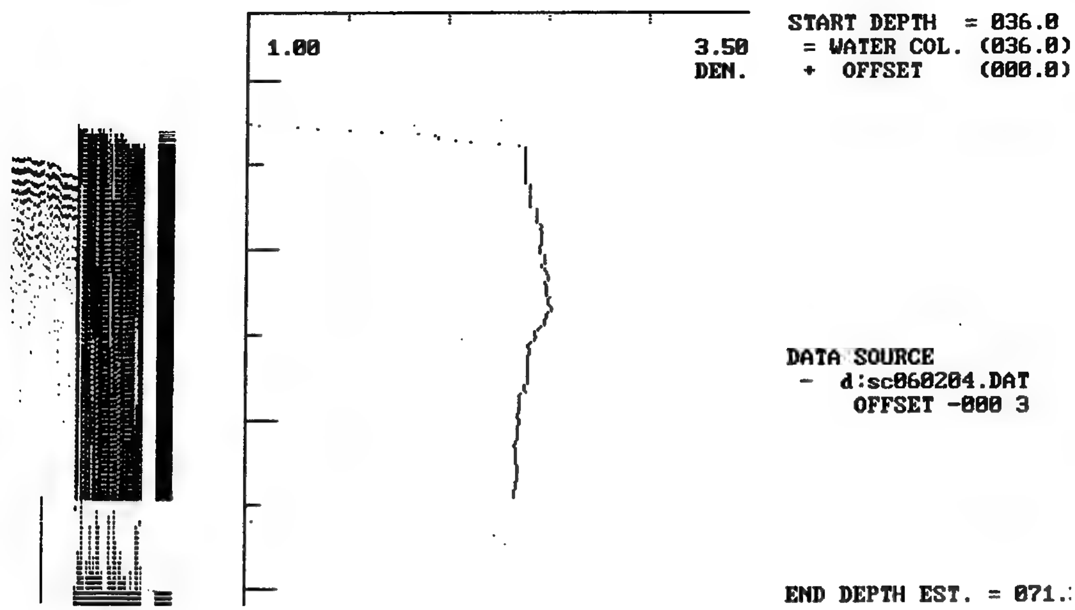

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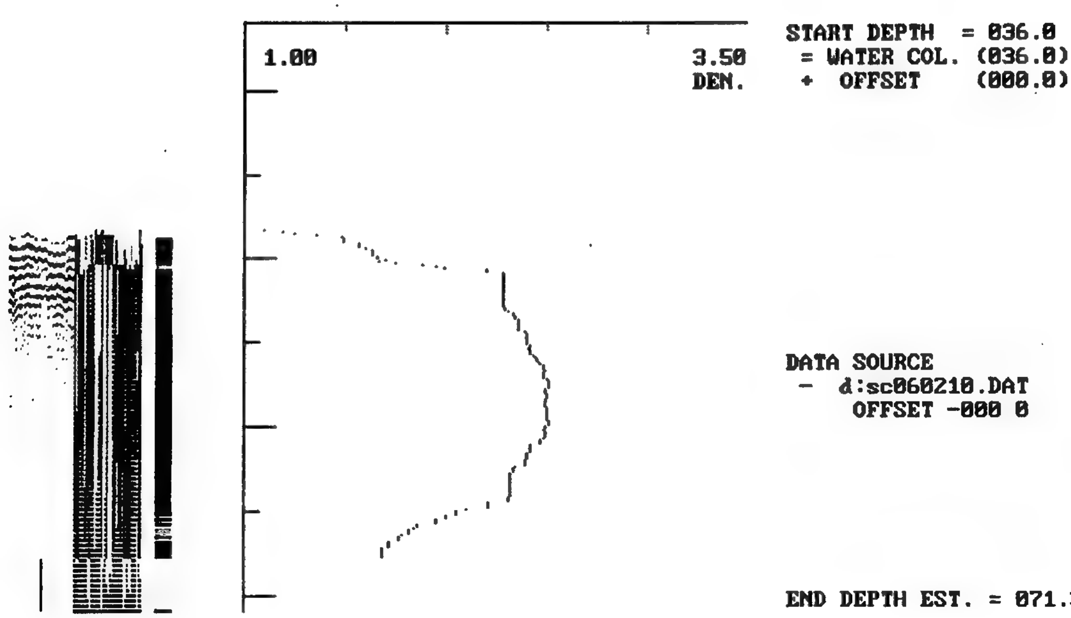

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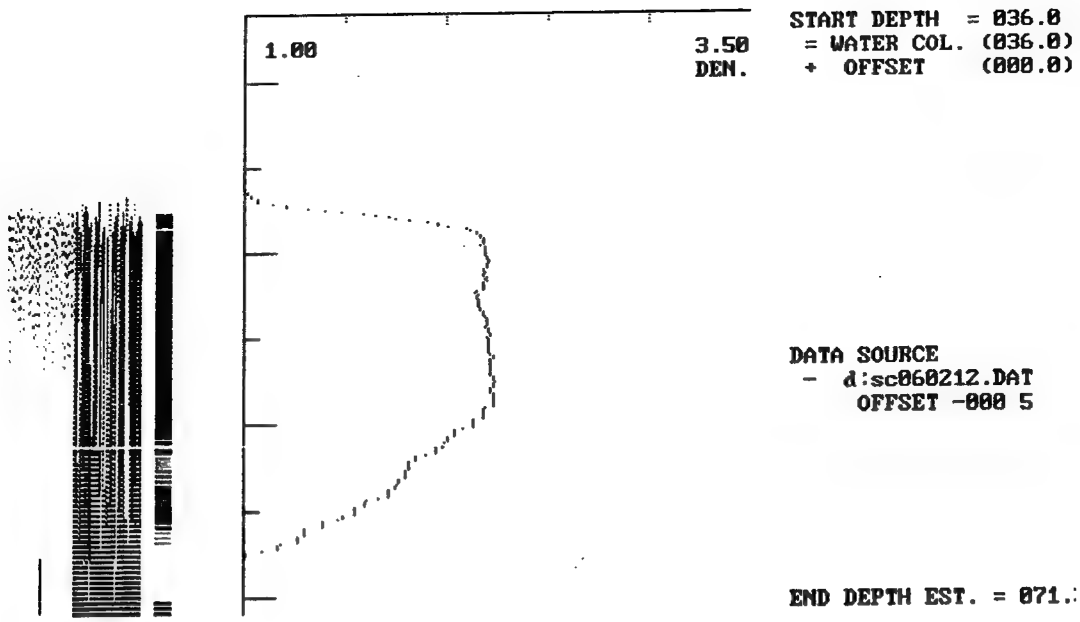
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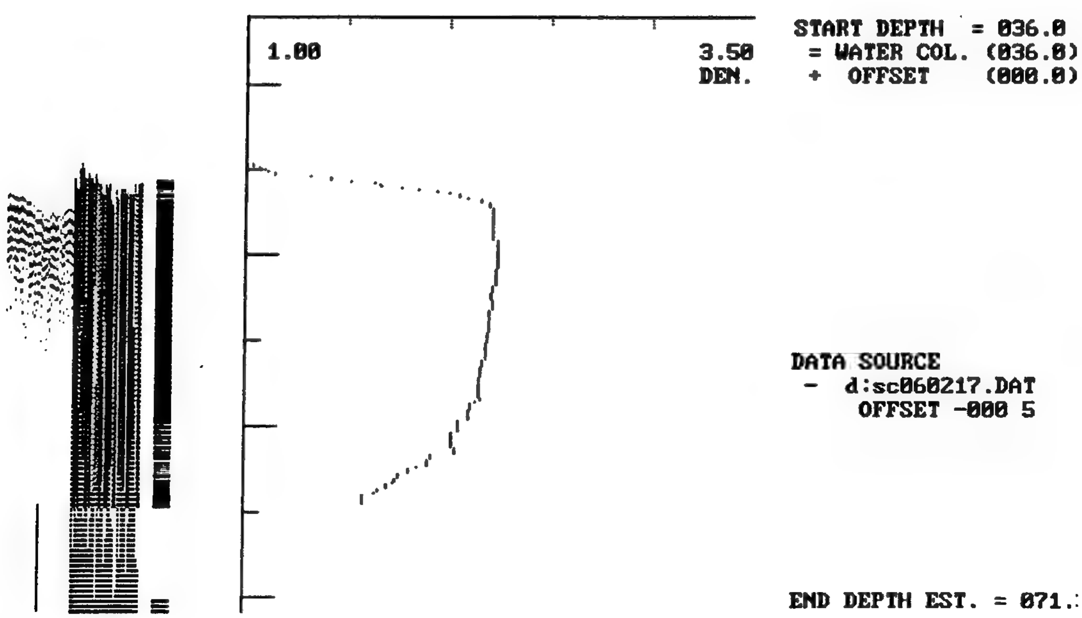
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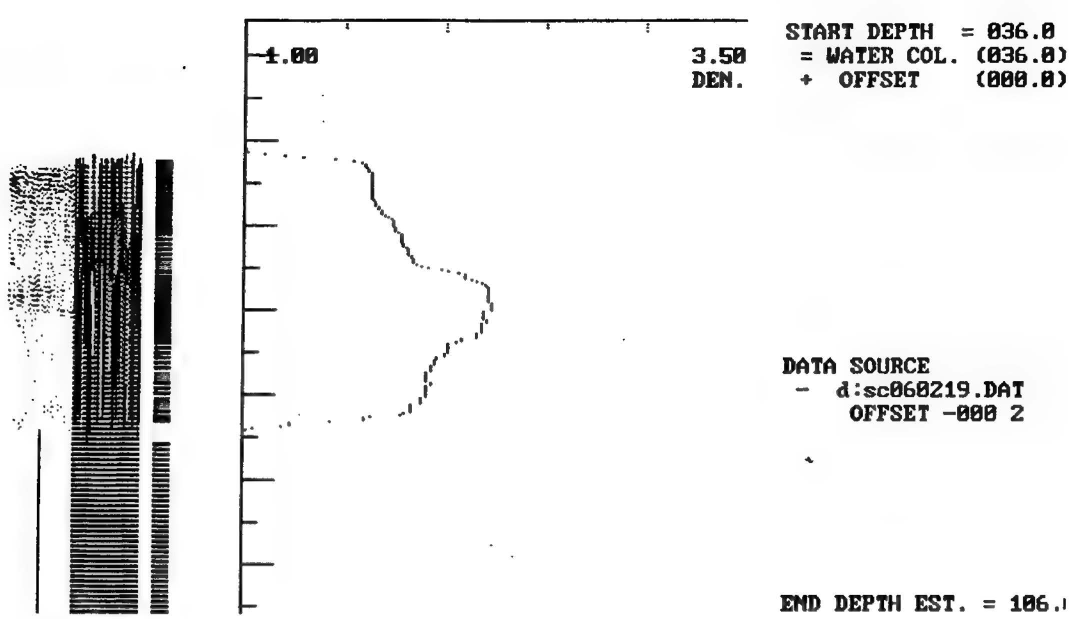
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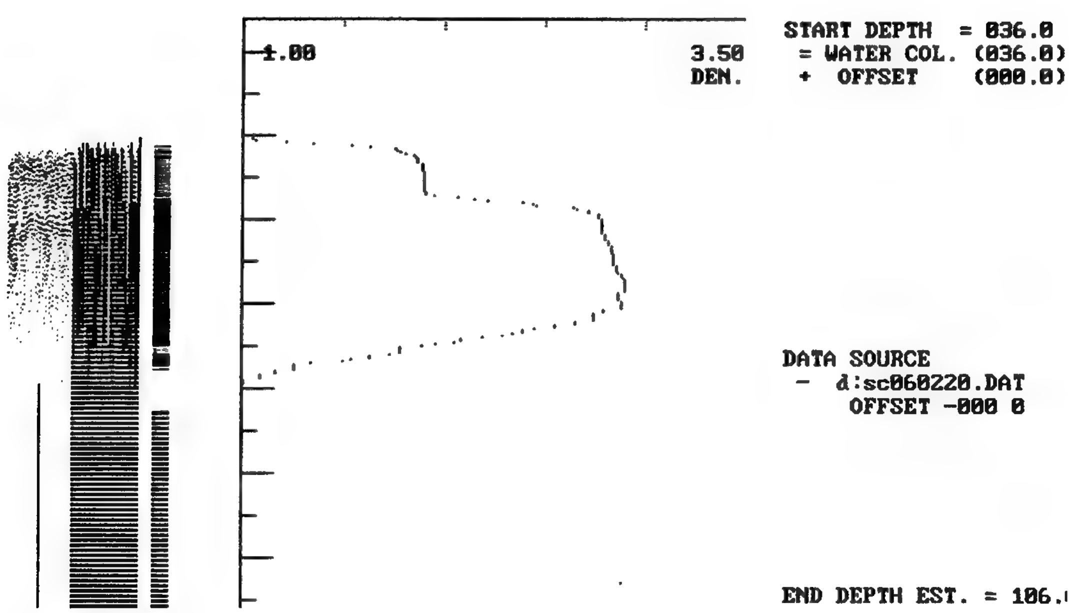
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+ OFFSET (000.0)
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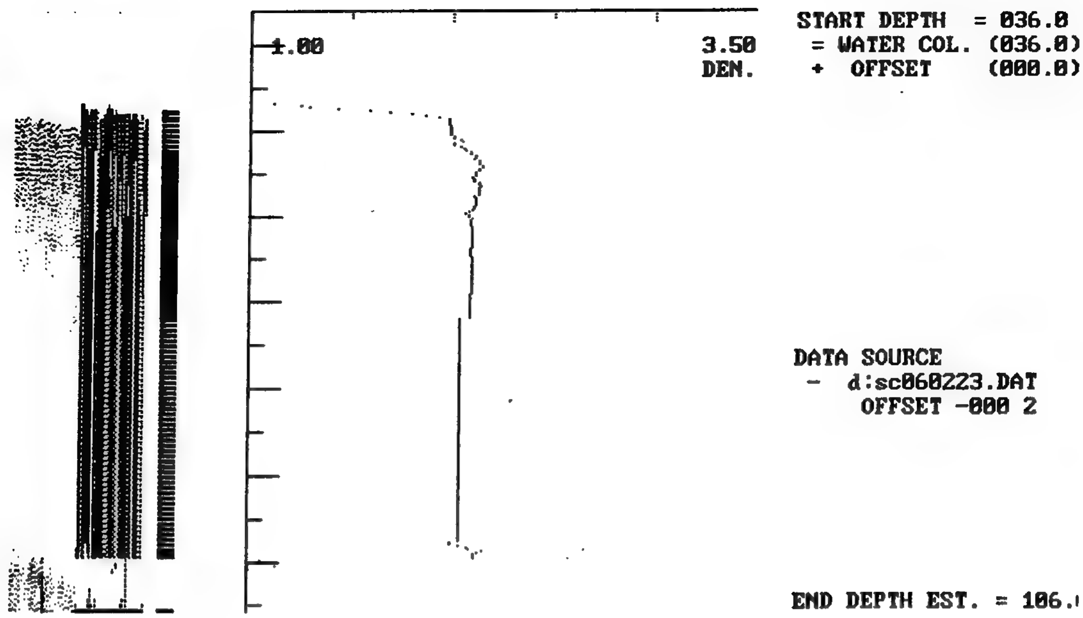
END DEPTH EST. = 106.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START DEPTH = 036.0
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- d:sc060223.DAT
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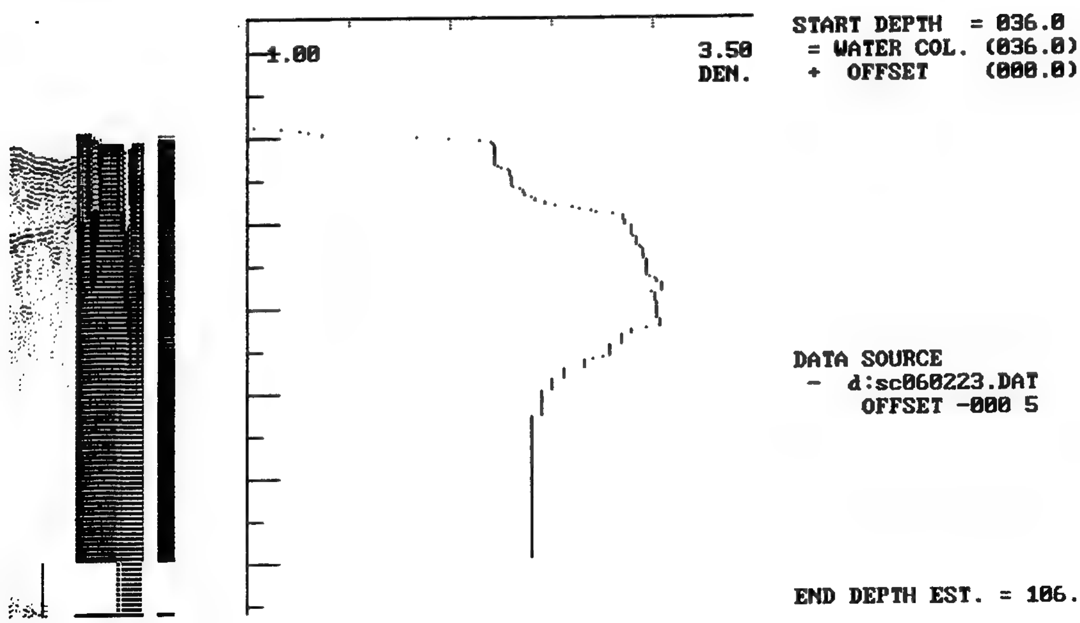
END DEPTH EST. = 106.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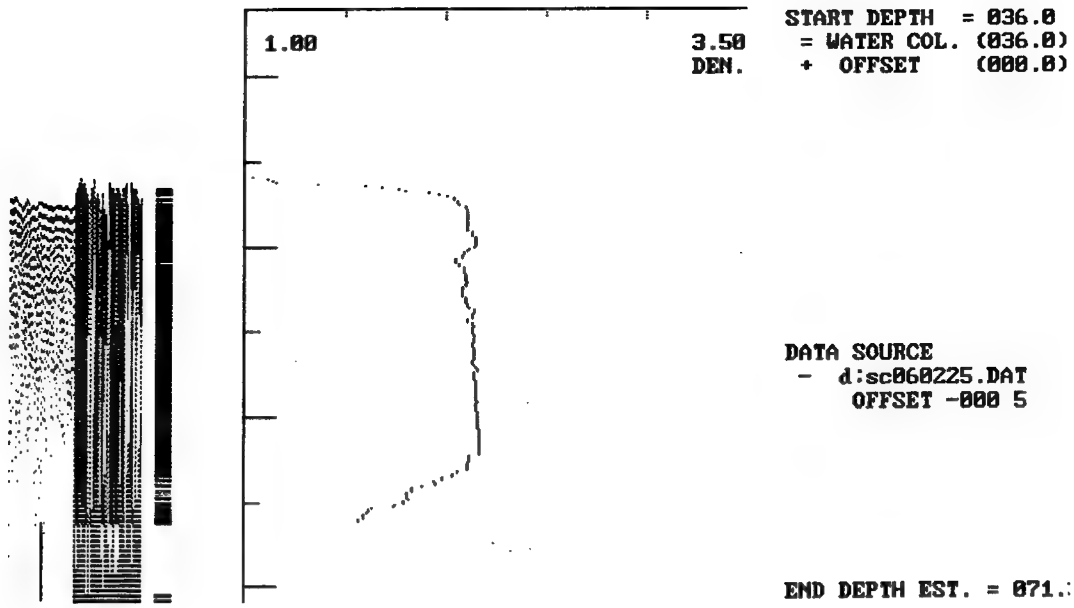
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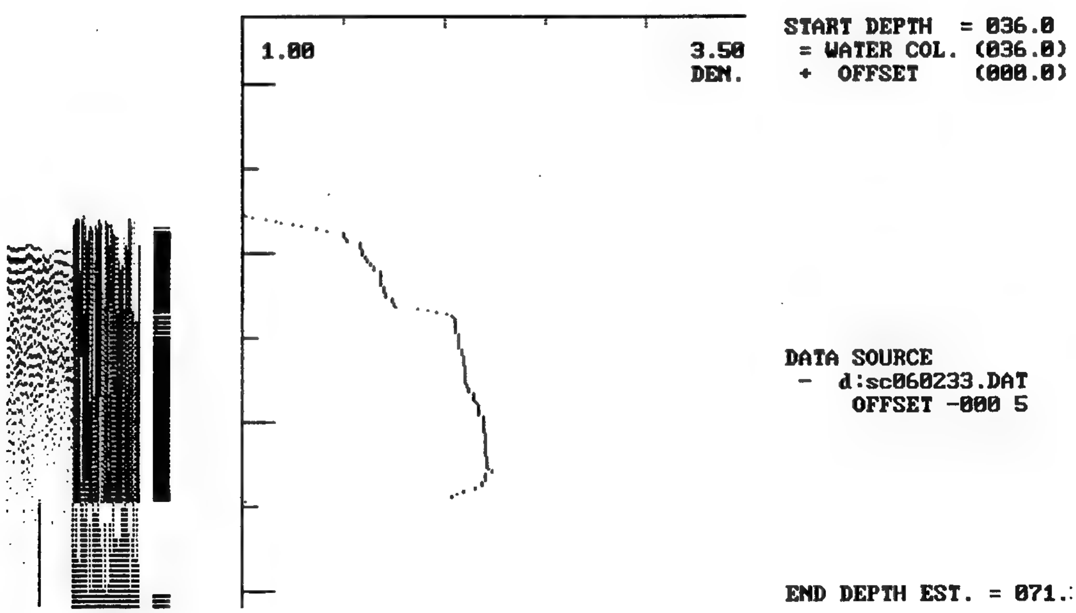
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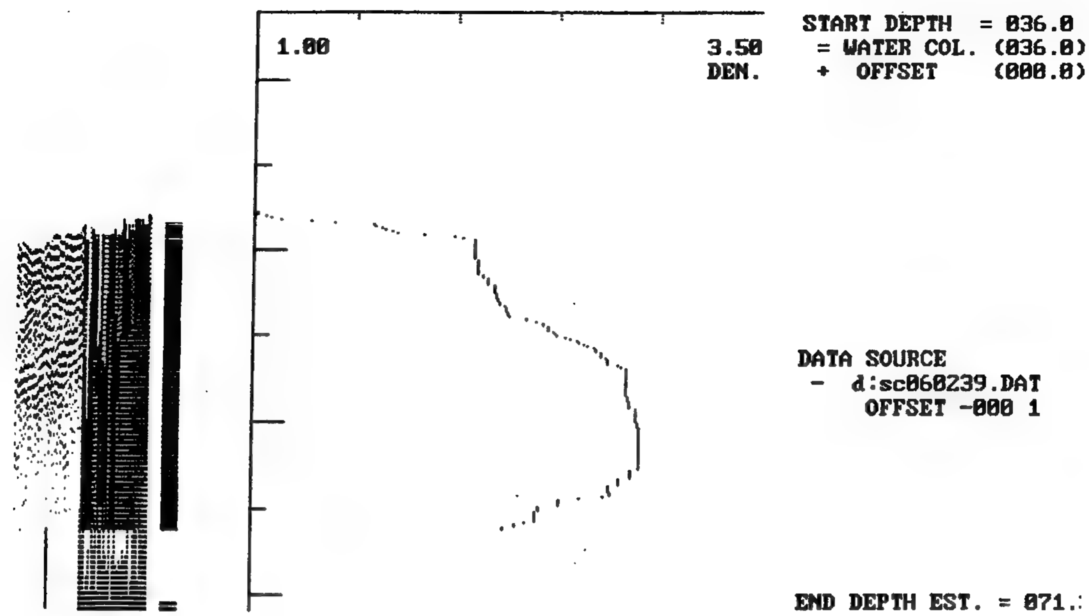
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= WATER COL. (036.0)
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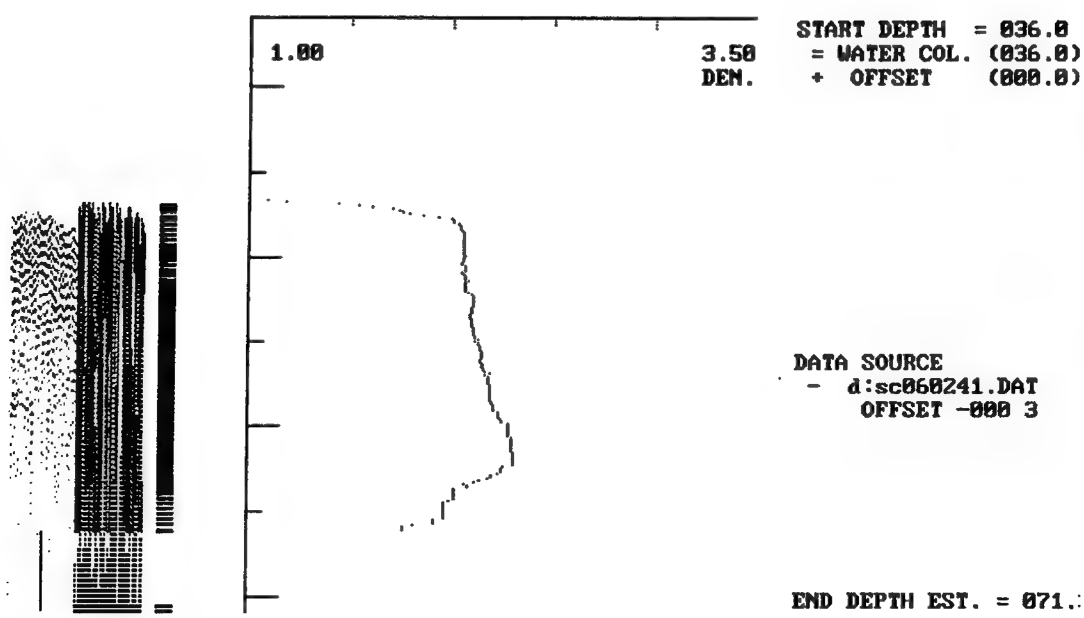
END DEPTH EST. = 071.: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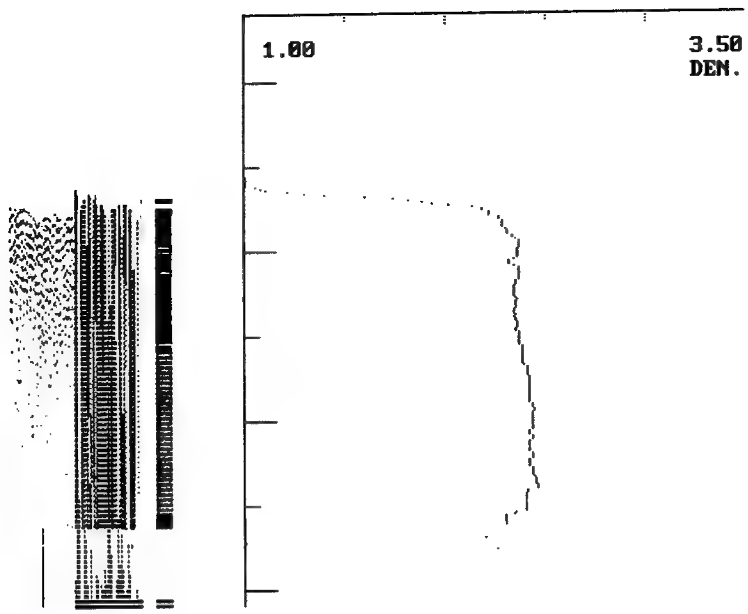

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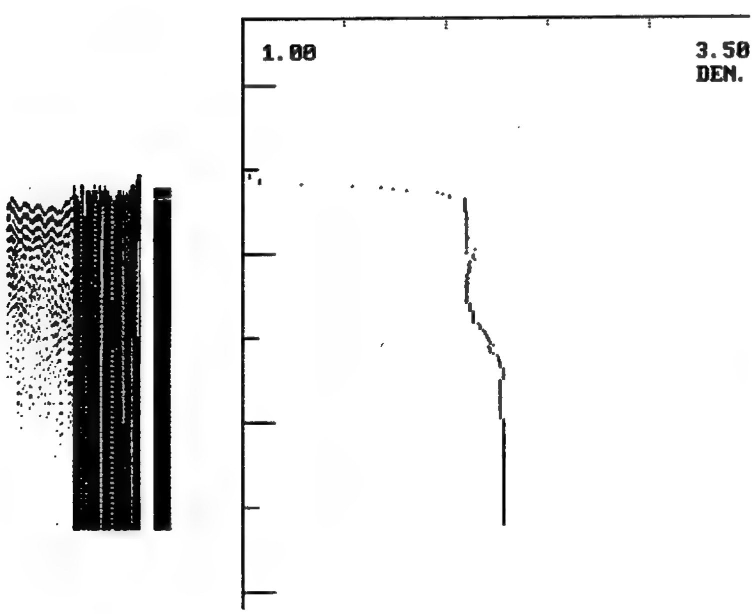
END DEPTH EST. = 071.



START DEPTH = 036.0
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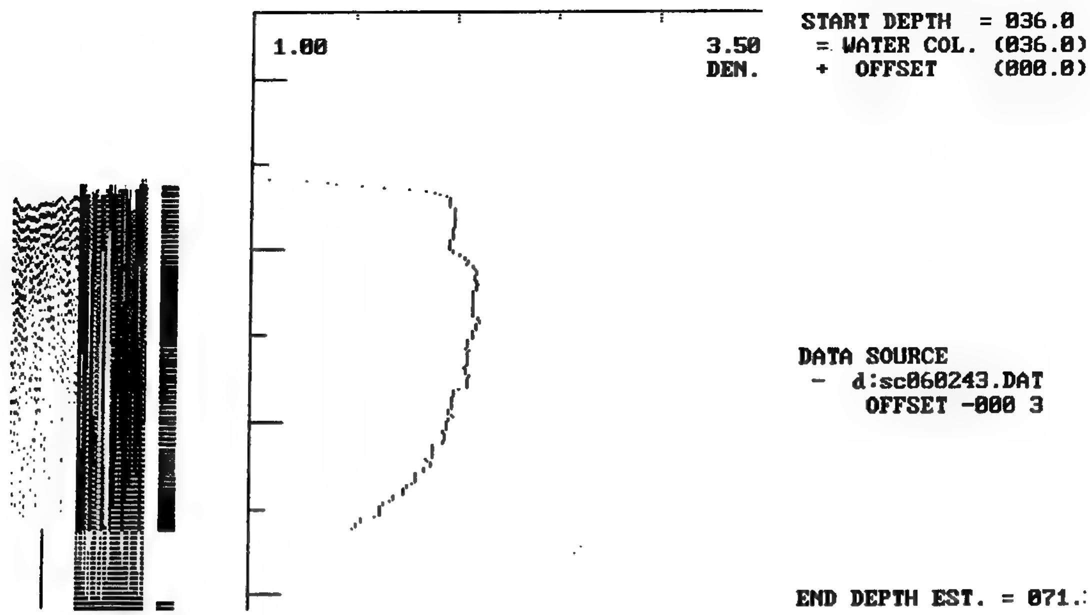
END DEPTH EST. = 071.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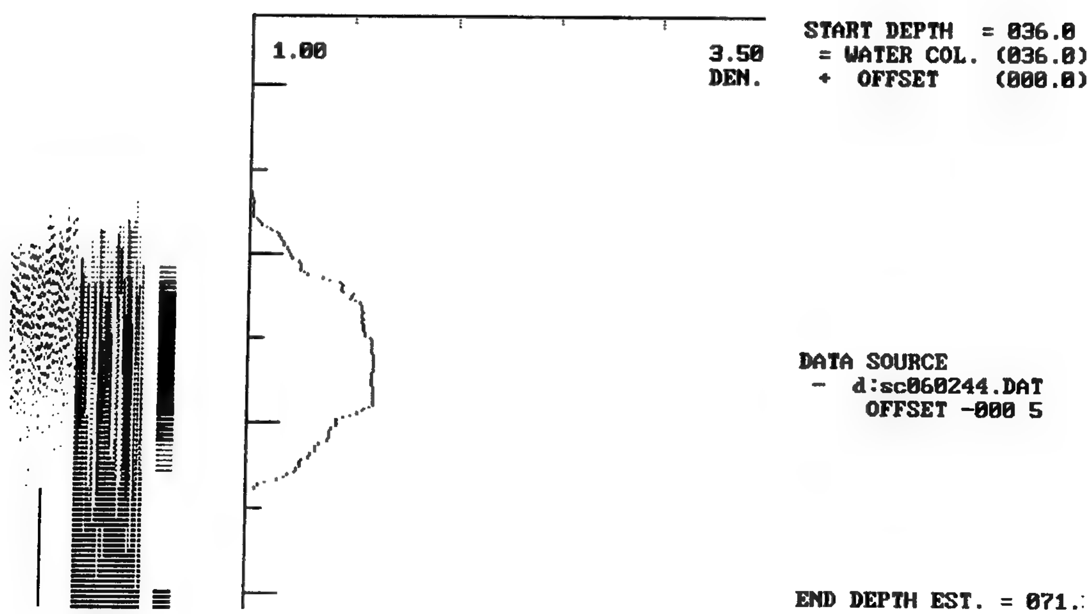
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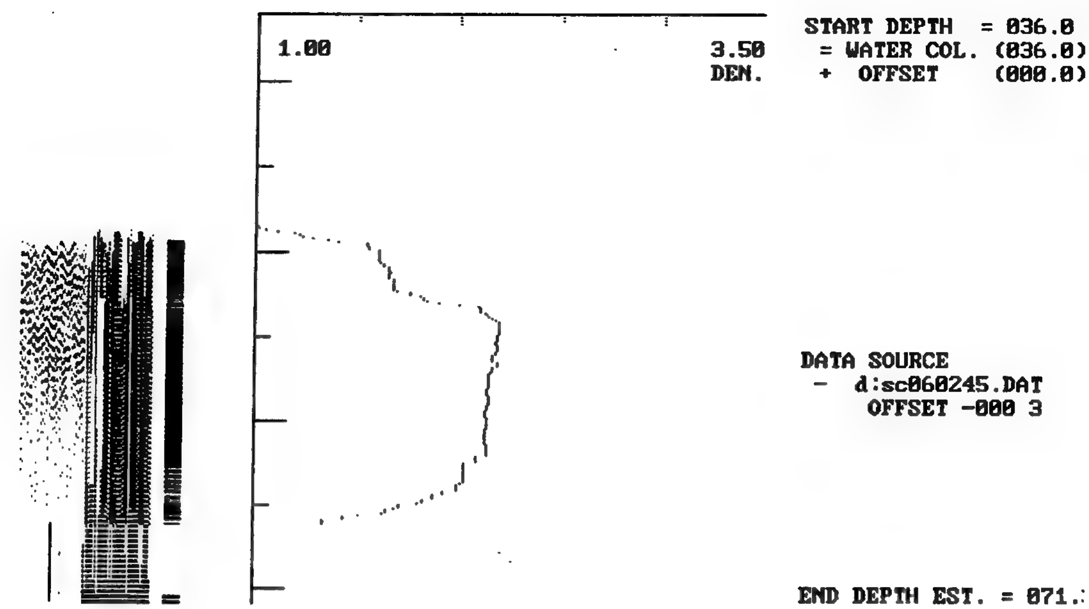
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+ OFFSET (000.0)
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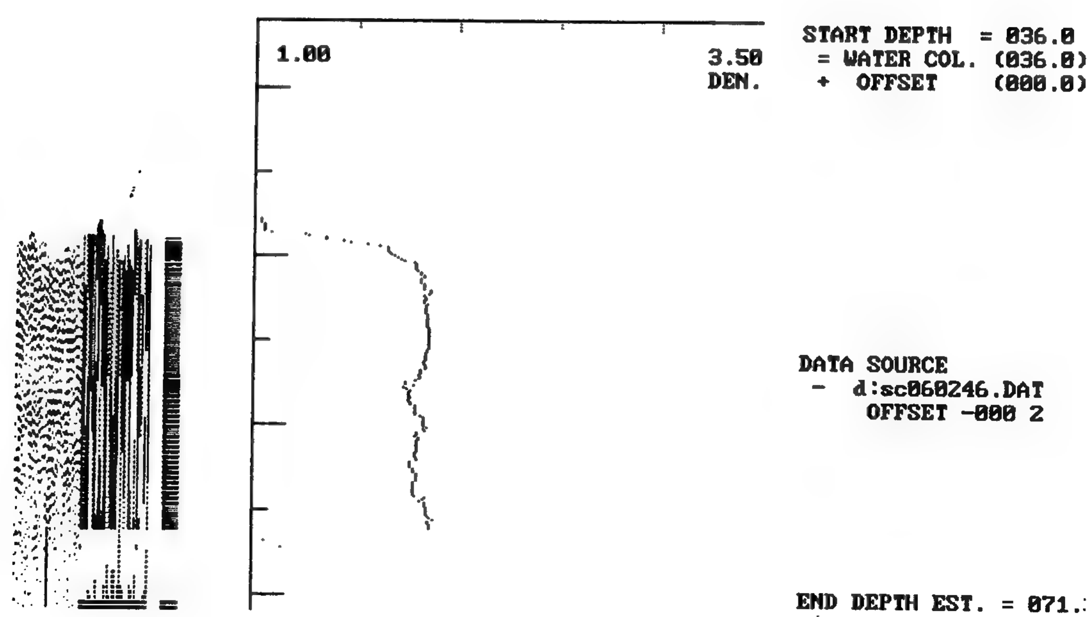
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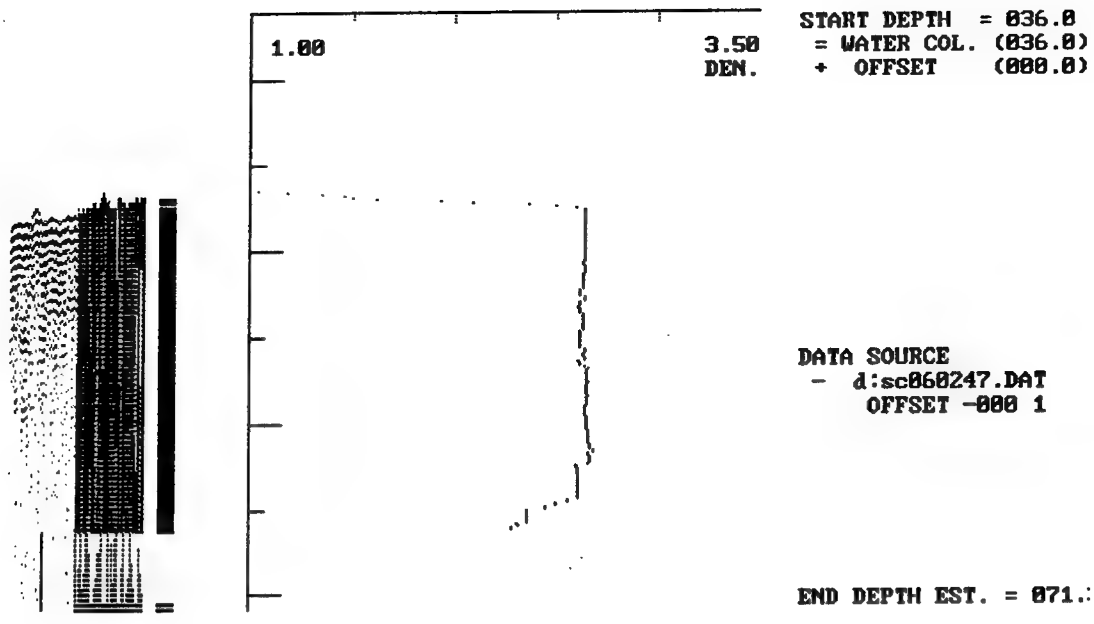
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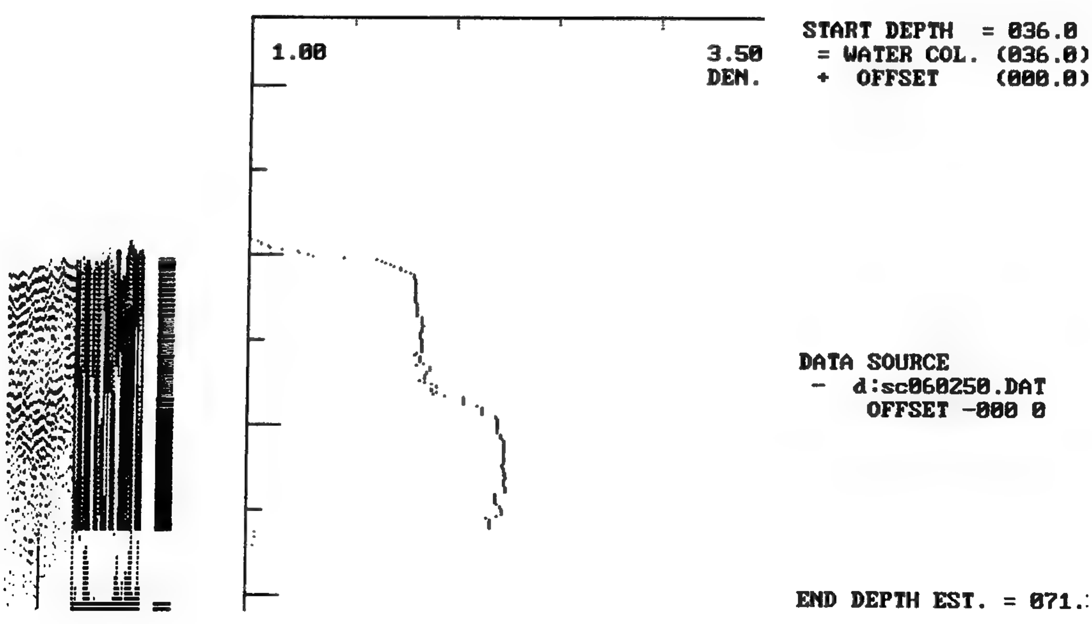
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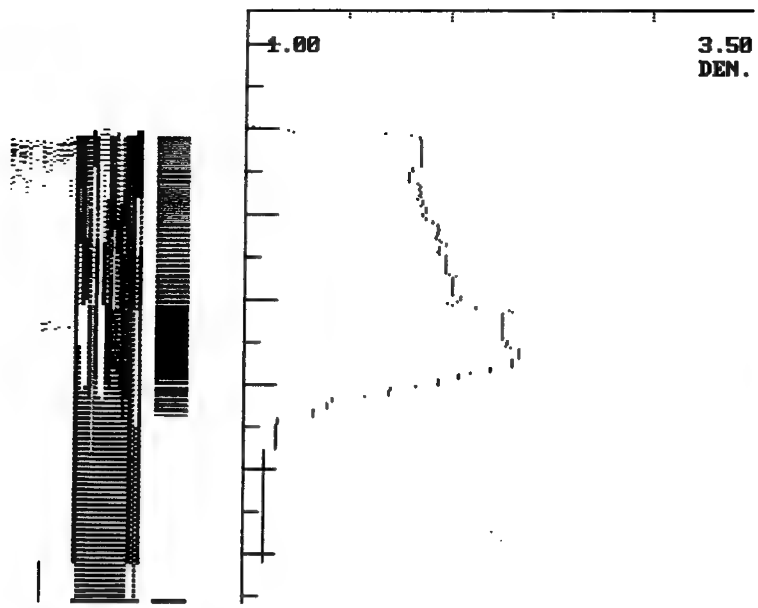

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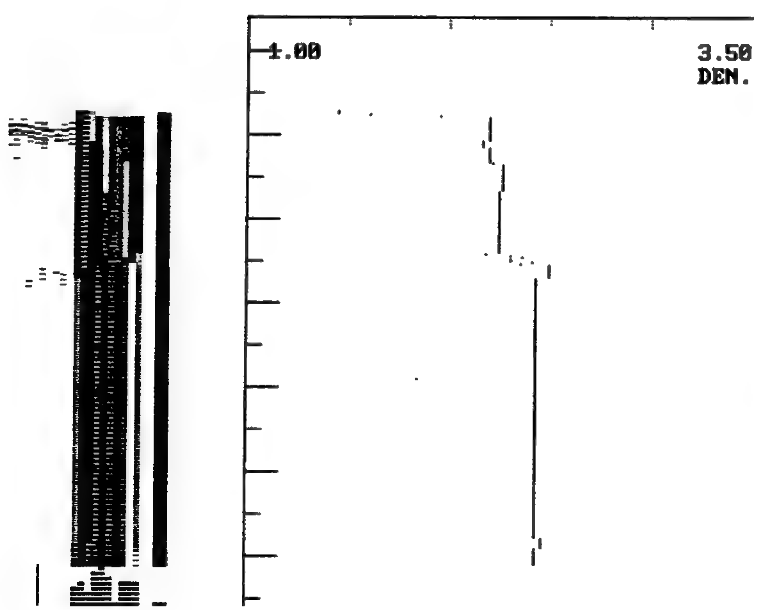

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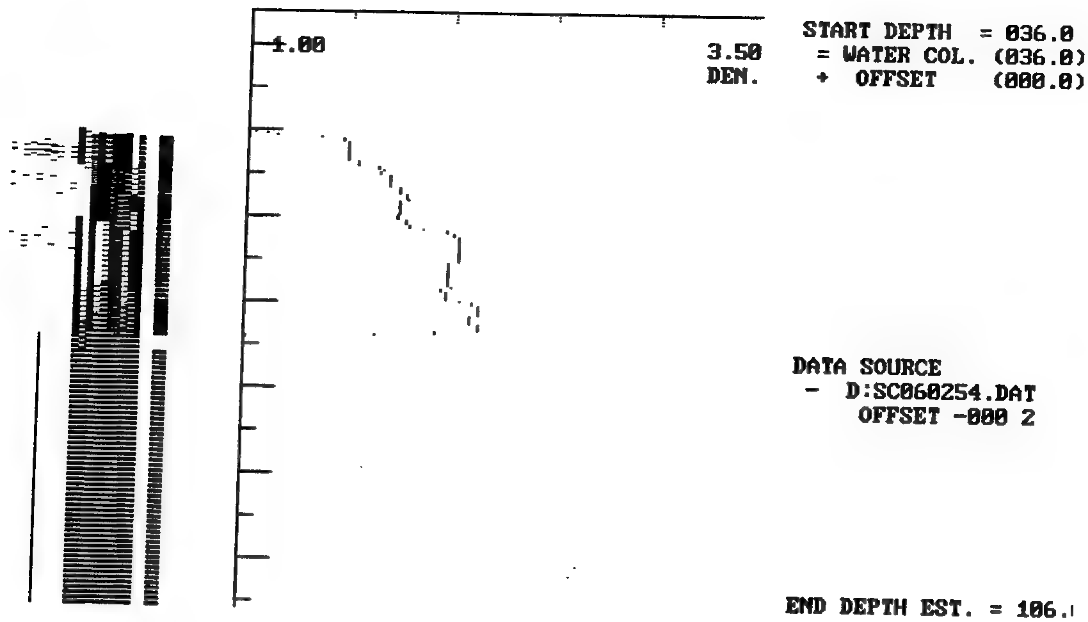
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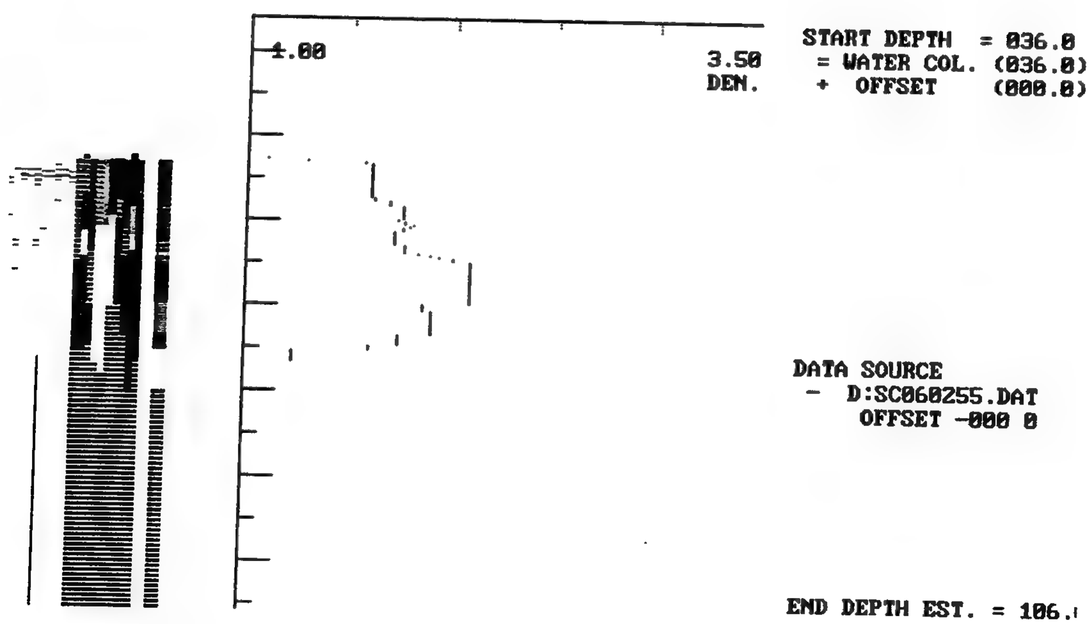
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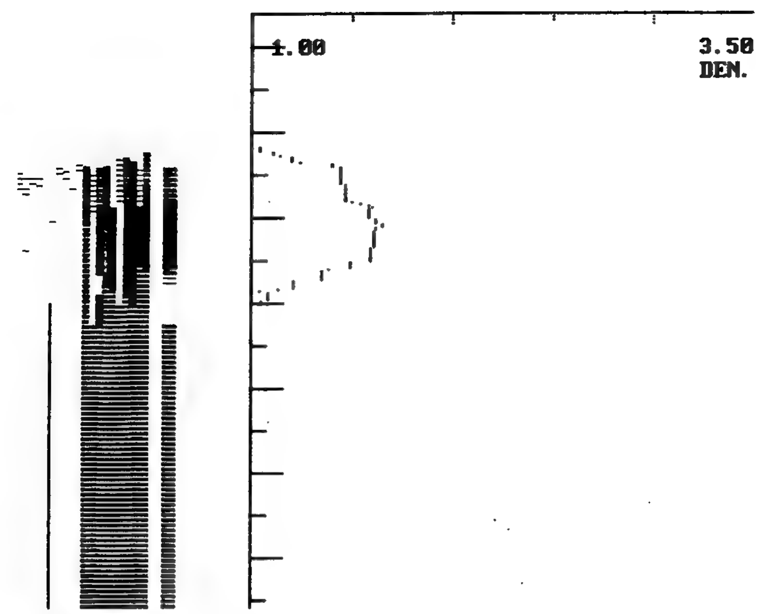

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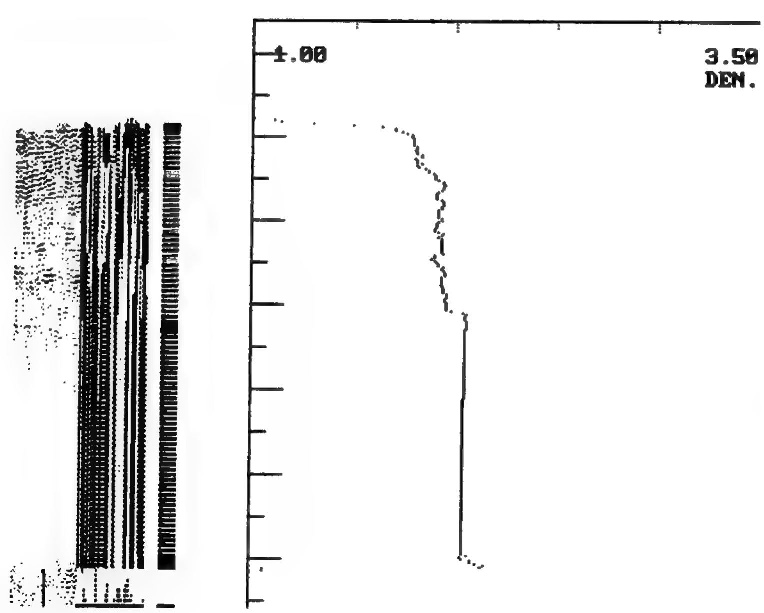

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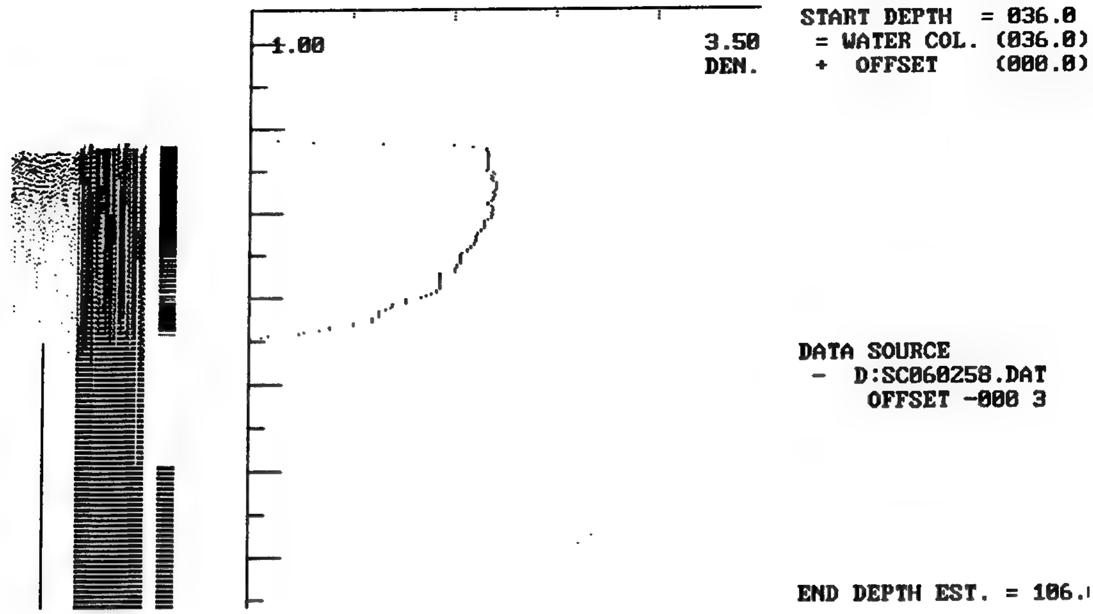

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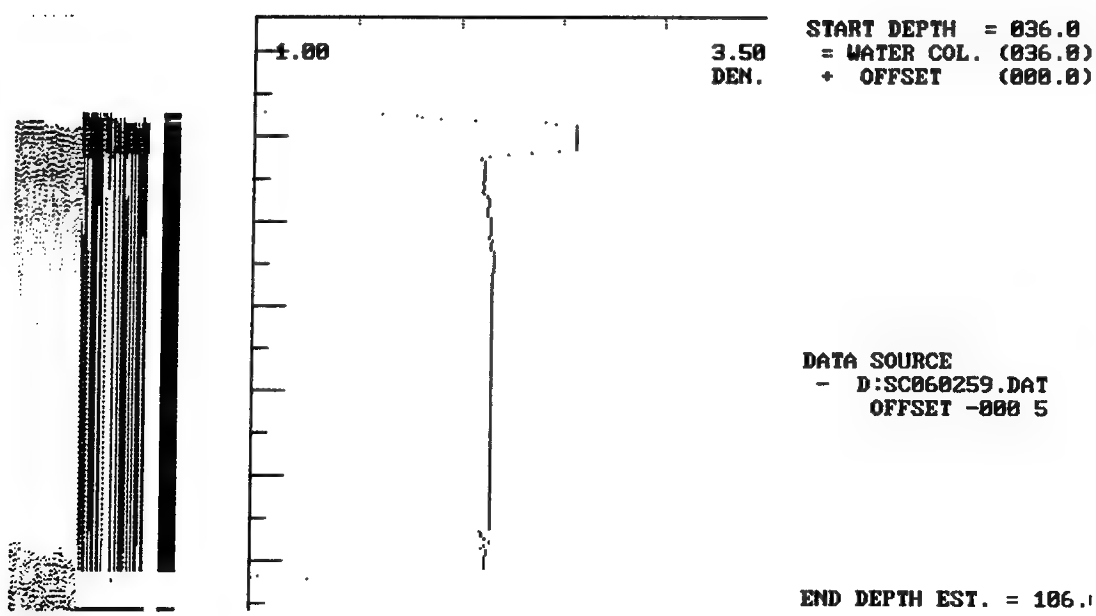

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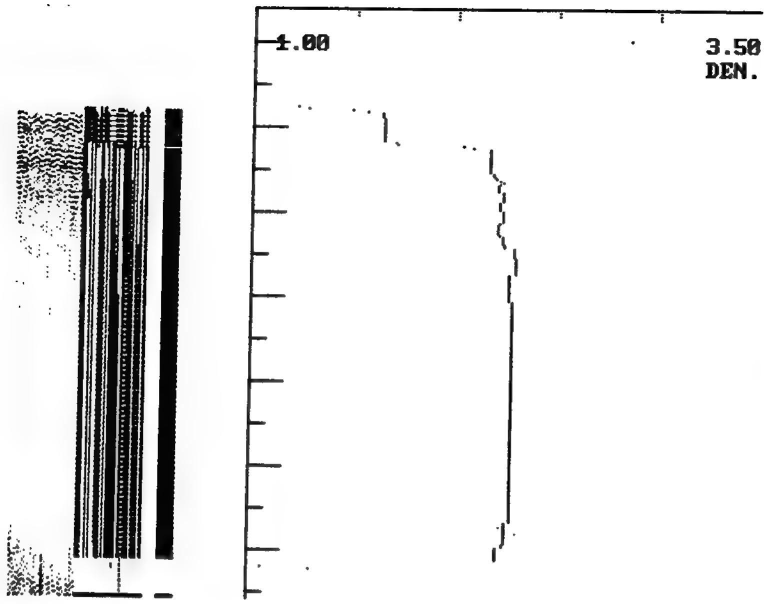

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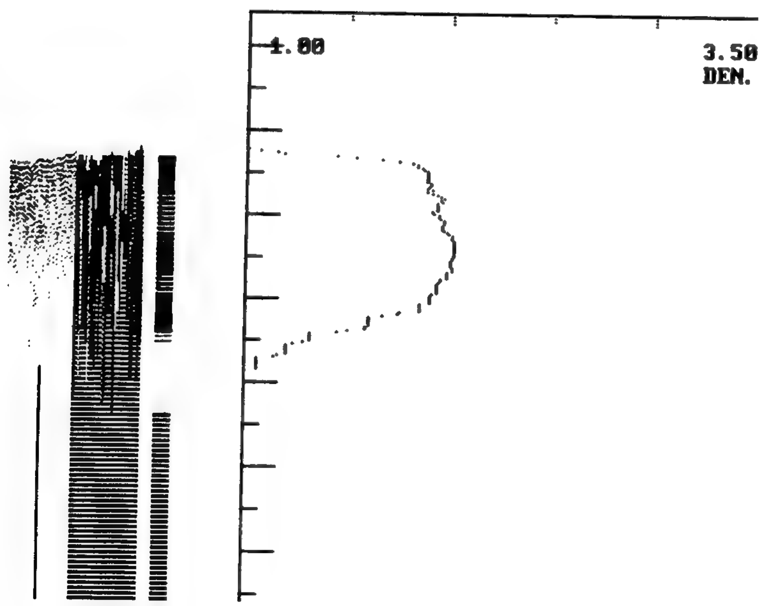

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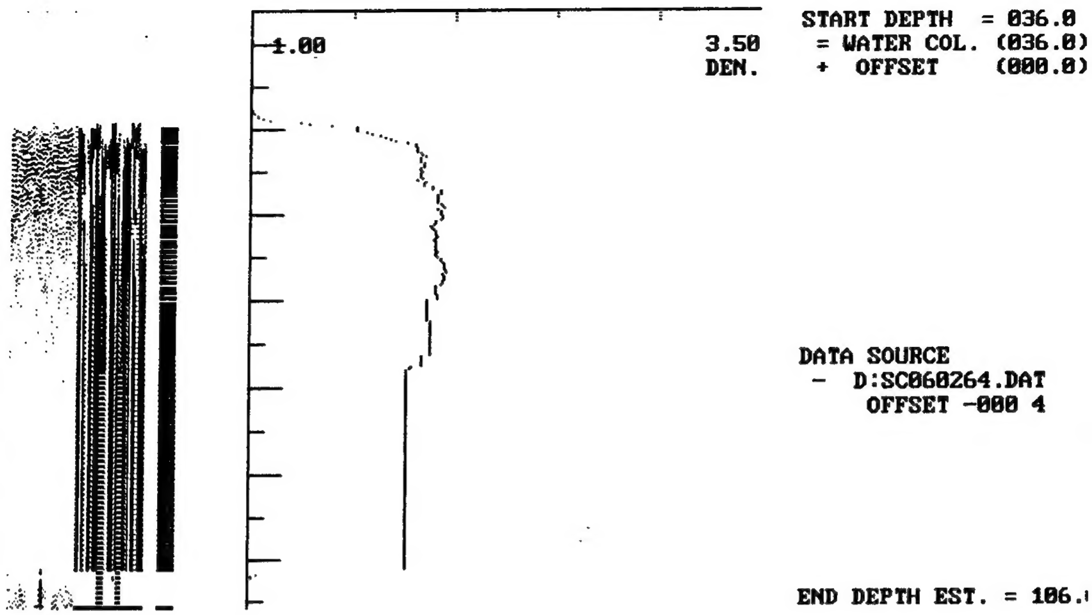
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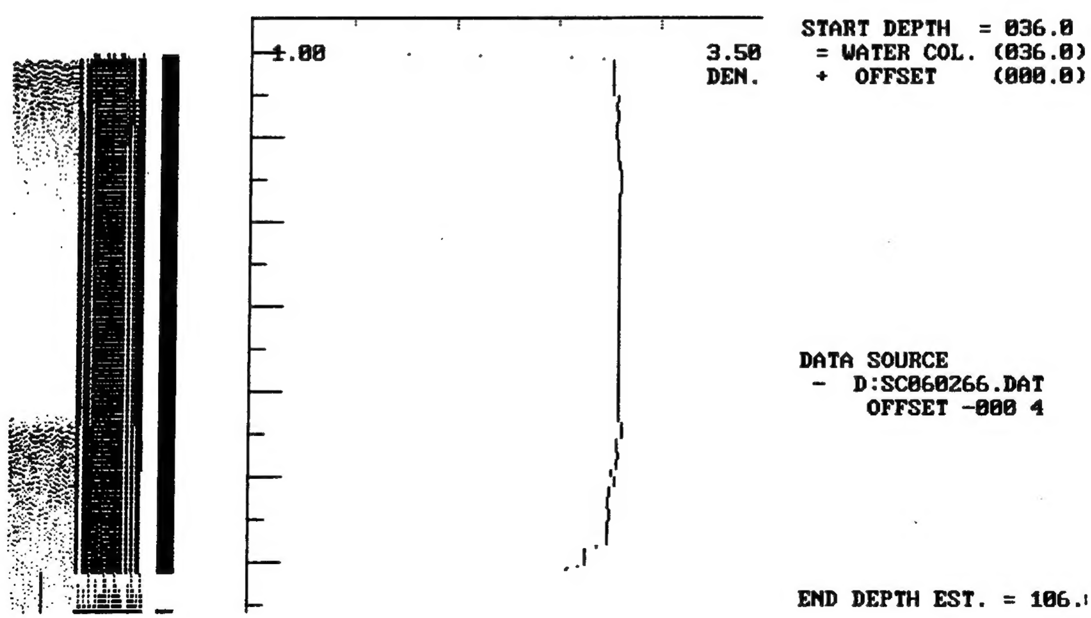
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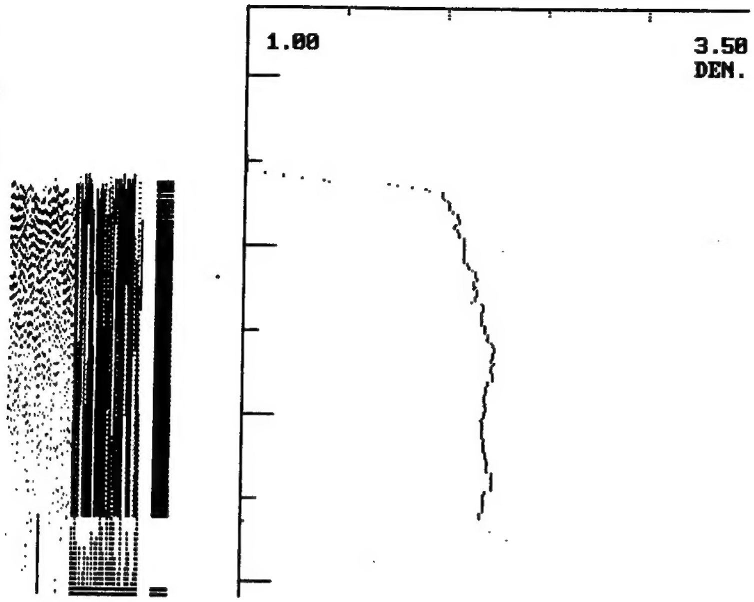

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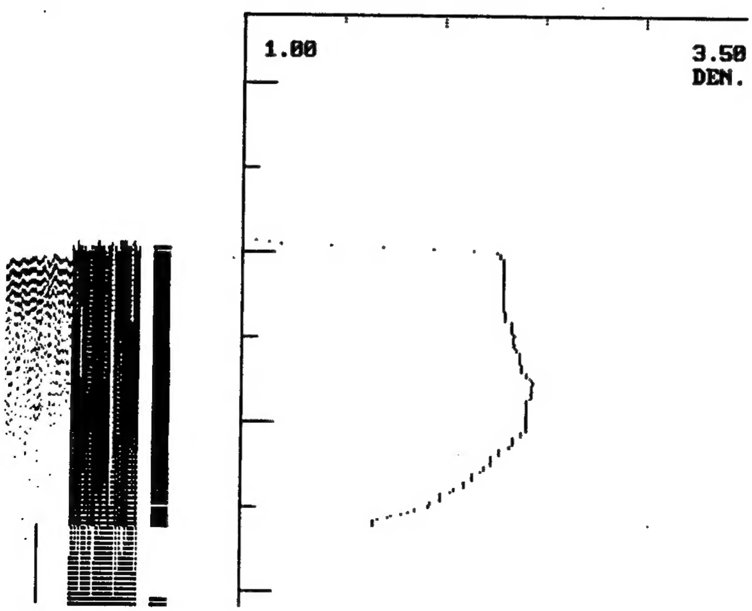

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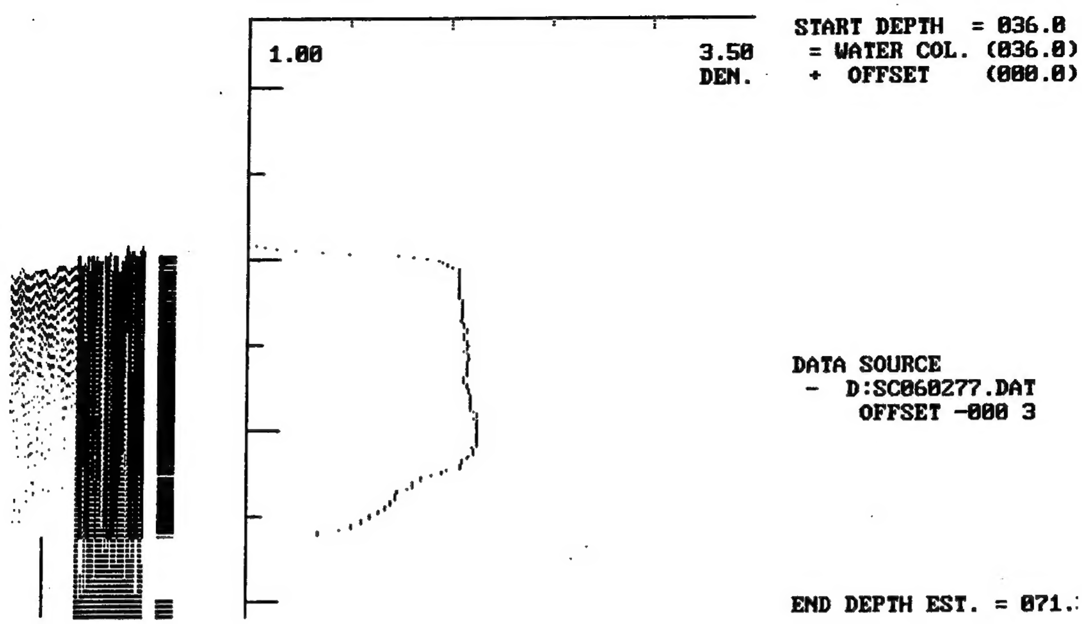
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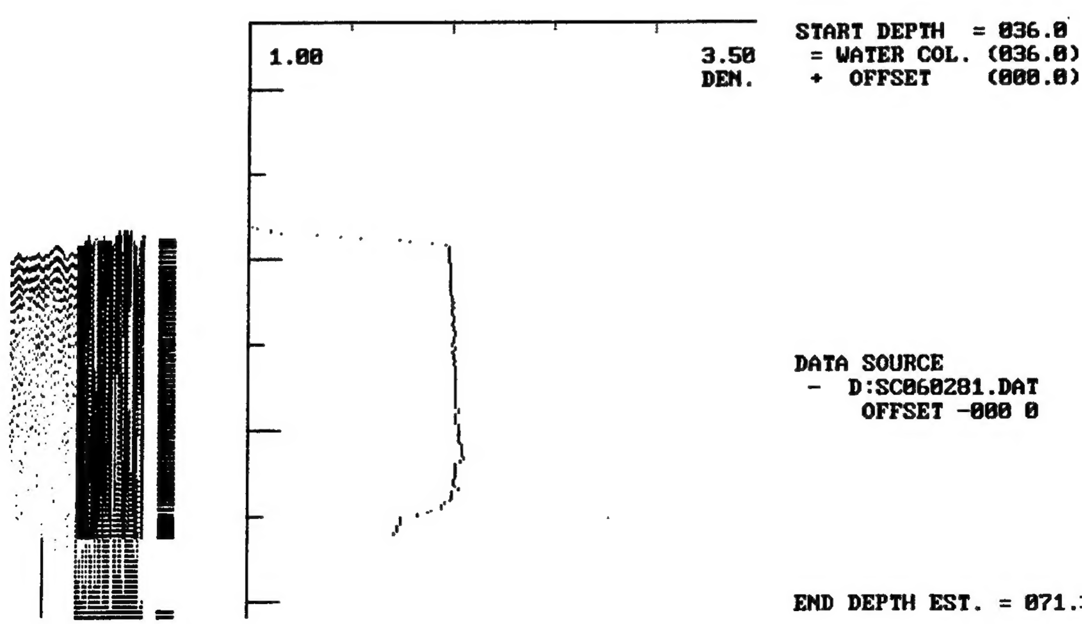
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OFFSET -000 0
END DEPTH EST. = 071.

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13. ABSTRACT *(Maximum 200 words)*

An acoustic subbottom profiling study has been performed along the center line of the Delaware River Main Channel from the Ben Franklin Bridge in Philadelphia, PA, to the entrance of the ship channel near the east end of Delaware Bay for the purpose of identifying sediment units within areas scheduled for dredging. The work was performed by the U.S. Army Engineer Waterways Experiment Station in support of the U.S. Army Engineer District, Philadelphia's Delaware River Main Channel Preconstruction and Engineering Design Study. The study is focused on deepening of the Delaware River Main Channel from 40 to 45 ft. The specific objective was to quantify the bottom and subbottom sediments in terms of in situ density and soil type to a depth of about 20 ft, where possible, below the bottom of the existing ship channel. Only a single profile line was requested to be surveyed down the center line of the channel. Data from 29 vibracores collected were correlated with 800- and 3,500-Hz acoustic reflection data using acoustic impedance to develop a geoacoustic model of the study area. Results are in the form of sediment profiles presenting the major reflection faces with descriptions of the engineering properties of the sediments and acoustically derived density versus depth plots herein referred to as "Acoustic Cores."

14. SUBJECT TERMS
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Delaware Main Channel
Geophysical methods
Marine sediments

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